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White-tailed Deer Utility Indices: Development and Application of an Analytical Method

Jodi A. Jacobson
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To the Graduate Council:

I am submitting herewith a thesis written by Jodi A. Jacobson entitled "White-tailed Deer Utility Indices: Development and Application of an Analytical Method." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Anthropology.

Walter E. Klippel, Major Professor

We have read this thesis and recommend its acceptance:

Paul W. Parmalee, Gerald F. Schroedl

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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WHITE-TAILED DEER UTILITY INDICES:
DEVELOPMENT AND APPLICATION OF AN ANALYTICAL METHOD

A Thesis

Presented for the

Master of Arts

Degree

The University of Tennessee, Knoxville

Jodi A. Jacobson

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Abstract

Full and partial carcass utility indices have been determined for many animals. The most widely utilized animal in eastern prehistoric North America is the white-tailed deer. However, whole carcass utility indices for this animal have not been investigated. In this thesis meat, marrow, and general utility indices are developed for *Odocoileus virginianus*. These indices are inspected for variation due to sex, age, and season. In addition, marrow fat percentages which may affect the accuracy of marrow utility indices, are investigated. Five deer have been collected from the ridge and valley region of East Tennessee. Four deer were acquired between mid to late fall. The fifth was acquired in mid spring.

Differences based upon age and sex are evident for utility indices. When divisions of utility are categorized as high, middle, and low utility there are both differences between males and females, as well as between juveniles and adults. When divisions are only categorized as high and low utility, all adult units fall into basically the same groupings; while differences still exists between juveniles and adults. These indices are also compared with those constructed by Binford (1978) for sheep and caribou, as well as Madrigal's (1999) investigation of white-tailed deer. These newly developed utility indices are applied to white-tailed deer remains from Westwood Plantation (16 CT490).

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Chapter I

Introduction

A primary interest of zooarchaeologists is the credible interpretation of skeletal part frequencies from archaeological sites. Skeletal part frequencies can be affected by what was chosen for human utilization and what has survived various taphonomic processes (Lyman, 1985). For the past 22 years one way of determining what was chosen for human utilization has been through the development and application of utility indices. These indices have been developed for large mammals in many regions of the world, yet none have thoroughly focused upon the large native mammals of the Eastern Woodlands of North America. The most widely utilized animal in prehistoric times in eastern North America was the white-tailed deer, *Odocoileus virginianus* (Emerson, 1979, 1980; Waselkov, 1978; Smith, 1974, 1975). Since full carcass utility indices for this important species have not been calculated, the only means of assessing skeletal part frequencies for this animal are based upon taphonomic processes and bone density studies (Lyman, 1994).

Though other researchers (Binford, 1978; Will, 1985; Jones & Metcalfe, 1988; O'Connell & Marshall, 1989; Borrero, 1990; Emerson, 1990; Gonalons, 1991; Lyman *et al.*, 1992; Blumenschine & Madrigal, 1993; Tomka, 1994; Savelle *et al.*, 1996; Savelle & Frieson, 1996, Outram & Rowley-Conwy, 1998; Madrigal, 1999) have examined meat and/or marrow utility indices for a variety of animals, few have looked at how differences in age and sex may affect these indices, or the ways these potential differences could affect the interpretation of the archaeological record. According to Smith (1975) the live weight of a white-tailed deer is primarily determined by five factors — geographical location, age, sex, seasonality of harvest, and population density and quality of forage. The same factors could be important when investigating meat and marrow utility indices.

Chapter II of this thesis focuses on previous researcher's methods of interpreting skeletal part frequencies and the development of various utility indices. These methods were reviewed in order to aid in the development of utility indices for white-tailed deer (*Odocoileus virginianus*). Archaeological and ethnoarchaeological investigations as well as applications of utility indices are examined to address the problems inherent with the use of utility indices as an interpretive tool.

Chapter III reviews wildlife literature and the valuable knowledge to be gained from that source. Wildlife research can help determine whether utility indices for one animal could or even should be applied to another. In addition, there are some questions as to whether certain indices, specifically the marrow index, are an accurate assessment of nutritional return. By using techniques developed by wildlife biologists this question can be answered.

In chapter IV the methods and procedures used in this project are presented. Detailed description of procedures are absent in most similar studies. Written detailed procedures makes it possible for the project to be replicated and tested. This is important since, due to the nature of the project, sample sizes tend to be small. Any addition of data can only add to the understanding of utility indices and, therefore, make the indices more accurate.

Chapter V presents the results for this project. All the animals are analyzed for differences based upon age, sex, and season. These differences are noted for the meat utility index, marrow utility index, and general utility index. The results of the kidney fat index and long bone marrow fat percentages are also listed. A comparison of the marrow utility and marrow fat percentages is made in order to examine possible problems of using only the marrow utility as a guide for nutritional return. The white-tailed deer utility index is also compared to the indices developed for other, closely related species. The standardized general utility index (SGUI) for the five deer in the study is compared to the general utility index (GUI) Binford (1978) found for caribou and sheep. There is a 3 ½ year-old male white-tailed deer in this study and a 3-5 year-old male caribou in the study by Binford. A comparison of these same-sexed and similar-aged animals is also made. Data developed here are compared to that retrieved by Madrigal (1999) for partial carcass indices of white-tailed deer.

In chapter VI the utility index is applied to the white-tailed deer remains recovered from a historic antebellum site in eastern Louisiana. The material from Westwood Plantation (16CT490) is plotted against the SGUI for the five animals in the study. Also the SGUI is plotted against taphonomic factors such as bone density. The material from Westwood is then examined in order to determine whether the remains represent differential choice or transport. Domestic pig remains are also analyzed for a comparative base of another medium-sized mammal. Statements are then drawn about the use and problems of applying utility indices.

In summary, this project is multi-fold and addresses many problems within zooarchaeology. It addresses the interpretation of skeletal part frequencies by setting up a utility index for white-tailed deer based upon full carcass values. It addresses the issue of whether marrow indices are an accurate estimation of nutritional return by comparing the marrow utility index of each animal with its long bone marrow fat percentages. The problems of using the index from one species to interpret material from another is addressed through investigation of interspecific variation. Lastly, the model is applied and problems with its use addressed.

Chapter II

History of Skeletal Part Frequencies and Utility Indices

Introduction

Zooarchaeology is the division of anthropology which attempts to interpret past human lifeways and the environment they inhabited through the identification and analysis of faunal remains. A major objective of zooarchaeologists is the credible interpretation of human prey skeletal part frequencies recovered from archaeological contexts. Skeletal part frequencies can reveal both cultural strategy and exploitation of species as well as acting taphonomic processes (Lyman, 1985). Also of concern are methods for determining the amount of meat or actual edible material represented by faunal remains at archaeological sites. The construction of utility indices help to satisfy these questions.

Skeletal Part Frequencies

The importance of skeletal part frequency studies has been established and researched for years and is important in analyzing butchering, transport, food preparation, disposal habits, nutritional analysis, activity areas, site function, economic institutions, and social organization (Reitz & Wing, 1999). The goal of this research is to develop a method to interpret white-tailed deer skeletal part frequencies based upon butchering, transport, food preparation, and nutritional analysis.

Previous researchers have proposed various methods for interpreting the faunal material from archaeological sites. White (1952) proposes that not all parts of a large animal, such as a bison, would have been brought back to camp. He states that "Since the lower limb does not carry any useable meat it is conceivable that it was chopped off and left at the place of kill to reduce the load" (White, 1953:162).

The "schlepp effect"was proposed by Perkins and Daly (1968) who assert the idea that the "larger the animal and the farther from the point of consumption it is killed, the fewer of its bones will be 'schlepped' back to the camp, village, or other area" (Daly, 1969:149). Perkins and Daly's (1968) well-known study of skeletal part frequencies, however, went largely unnoticed until a decade later when Binford's (1978) study of utility indices brought it to the forefront (Lyman 1994). Binford (1978) suggested that variability in the frequencies of anatomical parts at archaeological sites exists due to the dynamics of their use (Lyman 1994).

According to some researchers, bones of large animals may not be transported from the kill site to the habitation site and the likelihood of differential conveyance increases with the animals' distance from the habitation site (Read, 1971; Styles, 1981). Styles (1981:36) maintains that in order to study reasons behind differential deposition, "relationships between body parts and meat and marrow productivity (and potential as raw material) must be evaluated."

Optimal diet theory proposes that individuals will try to maximize their net gain while minimizing their energy expenditure. Smith (1974:290) in a study on Middle Mississippi exploitation found that "Middle Mississippi groups maximized their meat yield in relation to the necessary energy output in terms of man hours" by concentrating on seasonally localized food resources. He further states that:

> This exploitation strategy of maximization of return for energy expended through seasonal exploitation of localized, abundant food resources is not only a fairly common hunting pattern in hunting and gathering populations, but is also characteristic of many species of animals (Smith, 1974:290).

This theory of differential species selection should also be applicable to skeletal part selection.

Edible Meat Figures from Faunal Material

Aside from knowing what bones are present and what that means regarding procurement strategies, knowing exactly how much edible material is represented by the faunal remains is of major importance. Theodore White (1953) was the first to address this issue. His method was simple and consisted of first determining the minimum number of individuals of each species present at a site and then multiplying this figure by the average yield of useable meat for that species. This technique should work well for species that rapidly reach a characteristic maximum adult size. However, a great deal of introduced bias can exist for animals like white-tailed deer because they show a wide range of variation in live weight between individuals of the same population (Smith 1975). Stewart and Stahl (1977) tested White's method with a series of modern animals. Their results varied greatly from animal to animal and they concluded that a more accurate estimate was needed.

Smith (1975) puts forth a much more complex, yet more accurate, method of estimating the meat yield from archaeological sites. He focuses his method on white-tailed deer as it is such an important species in prehistoric human diets of eastern North

America. His method establishes a series of edible meat averages of modern species based upon the five factors affecting live weight: geographical location, age, sex, seasonality of harvest, and population density and quality of forage. By determining the sex ratio, age composition, and season of death of deer represented in archaeological sites, the appropriate averages can be applied. This method is an improvement over White's, but it still has problems. The minimum number of individuals (MNI) present for each sex, age, and season are expanded to material where this data is unknown and applied to the site. Therefore, if there were six MNI that were male and three MNI that were female, but a total MNI for the site of 30, this 2:1 ratio would be applied as if 20 of those individuals were male and 10 were female. This is a fallacy found in much of archaeology due to the scant and fragmentary nature of much of the record, and therefore a bias often overlooked.

Emerson (1978) offers an alternative method to Smith (1975). Emerson's method is also directed toward white-tailed deer, but eliminates the need to account for factors affecting live weight. Through regression analysis, he uses astragali length and width to estimate the live weight of archaeological material based upon similar regressions of modern animals. This method is an improvement over previous work in that it is more practical in its application. However, it too has problems. Astragali are low utility parts and, as such, are less likely to be present in a habitation site where food consumption is occurring. This means that reliance solely on the astragali could lead to a significant under-representation of edible meat availability.

Lyman (1979:539), in a critique of previous methods for determining meat yields, states that the main problem with these methods is calculating the degree of carcass consumption. He points out that "an attempt must be made to distinguish consumed meat from available meat" and that "it would be illogical to assume that the entire animal was consumed if it is not represented in the bone sample". Lyman suggests using "butchering units" instead, relying on the amount of meat represented by the individual butchering units found. In his application he found the use of butchering units over earlier edible meat estimation methods much more reliable. The similarity of this method to utility indices is representative of the future direction that these types of analysis are taking.

Indices Development

Meat and/or marrow utility indices have been developed for a variety of animals including sheep (Binford, 1978), musk ox (Will, 1985), red kangaroo (O'Connell & Marshall, 1989), bison (Emerson, 1990), horse (Outram & Rowley-Conwy, 1998), guanaco (Borrero, 1990), llama (Gonalons, 1991; Tomka, 1994), phocid seals (Lyman *et al.*, 1992), otarriid seals (Savelle *et al.*, 1996), harbour porpoise (Savelle & Friesen, 1996), caribou (Binford, 1978; Jones & Metcalfe, 1988), some East African ungulates (Blumenschine & Madrigal, 1993), and white-tailed deer (Madrigal, 1999; Madrigal & Capaldo, 1999). Methods utilized by these researchers were examined to determine the best technique for developing meat and marrow utility indices for white-tailed deer.

Lewis Binford (1978) was the first to construct utility indices. He worked with three animals: an adult prime male caribou, a 7 ½ year-old female sheep, and 6 month-old lamb. He used different techniques to butcher and dismember each of the animals. Therefore, the weights collected were not equivalent so the data for the three animals are not comparable. He created a meat utility index (MUI), a marrow index (MI), and a white grease index (WGI) for all three animals which he combined into a generalized model, the general utility index (GUI). He standardized the GUI to account for the fact that some parts may be transported from a kill site in higher proportion than the GUI would predict because they are adjacent to highly valued parts. Binford refers to these bones as "riders". He compared his data to the percentages of the corresponding bones at Nunamiut sites. By establishing an economic utility for each part, Binford found that parts with a high quantity and quality of edible components, or parts of high economic value, were preferred to parts with low quantity and quality of edible components, or parts of low economic value. High economic value parts were less likely to occur at kill sites and more likely to occur at processing or habitation sites while the reverse was true for low economic value parts.

Jones and Metcalfe (1988) reexamined the utility indices developed by Binford (1978) with an emphasis on the marrow index. They feel that in his need to represent all aspects of nutrition, Binford over-complicated the marrow index. They found that Binford's inclusion of the oleic assay weakened the marrow index rather than strengthened it and that the use of marrow cavity alone is actually a better indicator (Jones & Metcalfe, 1988). They apply a much simpler method and state that in the future researchers doing economic analysis should consider "the benefit or reward from the activity and the cost" (Jones & Metcalfe, 1988:422)

Borrero (1990) established a meat utility index for guanaco, and animal closely related to the llama. The derivation of his index is very simple and easy. He took the whole weight of meat and bone and subtracted the dry bone weight. He did not account for "riders" and did not look at marrow indices. He did, however, create a standardized meat and marrow index using Binford's (1978) marrow values for caribou and his own guanaco meat values (Lyman, 1992). This is somewhat disturbing as the two species, *Lama guanicoe* and *Rangifer tarandus*, are not exactly closely related.

Gonalons (1991) established a utility index for llama using one castrated adult male. His main goals were to look at the meat production of the llama, compare his indices to that of Borrero's (1990) for guanaco, and to discuss the possibilities for the maximization of strategies in traditional technology. Basically he followed the methods of Binford (1978) and Metcalfe and Jones (1988) in establishing his indices. He found that there were differences between guanaco and llama and suggests that indices should be developed for each species and applied only to that species in order to be accurate (Gonalons, 1991).

Tomka (1994) also developed a utility index for llamas. He used three animals: a 2-year-old male, a 5-year-old castrated male, and a 10 ½ year-old female. Tomka divided the animals based upon ethnoarchaeological data of llama butchery for home consumption. He divided units into distal and proximal as well as measured all individual vertebrae separately. He established his indices in three different sets of groupings to account for differences in butchering practices. Tomka also compared the animals by age and sex. However, he developed his index in order to apply it to an archaeological assemblage that had not been analyzed by sex. As a result, for application purposes he averaged the meat weight from the three animals to "obtain a single mean total weight figure for each element" (Tomka, 1994:62). Unfortunately, Tomka (1994) did not look at marrow indices, otherwise his work would represent the most complete species indices developed to date. It is also interesting to note that he did not mention the indices developed by Borrero (1990) or Gonalons (1991), or attempt a comparison with either.

O'Connell and Marshall (1989) developed a utility indices for red kangaroo. They not only examined full carcass utility and meat and marrow utility, but also added an investigation of the utility of various internal organs. They used four animals (two males and two females) for the construction of the indices and also examined how they differed based on sex. Their project focused more on an ethnographic examination of carcass choice under varying conditions for the Alyawara of Central Australia than on interpretation of archaeological material.

Emerson (1990) constructed her indices on bison based upon four individuals of varying age, sex, and season of death. She used an adult 16 ½ year-old female and a 1 ½ year-old male collected in the fall, and a 6 or 7-year-old female and a 4-year-old male collected in the spring. Her research is incredibly comprehensive and detailed. She separated out muscle weight, fat weight, and non-edible tissue weight such as tendons. She analyzed soft tissue for actual nutritional value and studied in detail the variation of fat distribution in bison. Her index was modified to account for "riders" and she distinguished between proximal and distal long bones. She averaged the different animals together to get a standardized index she could apply archaeologically (Emerson 1990). In application she "detected utility strategies that suggest that appendicular and axial skeletons may not be explainable with the same utility model" (Lyman, 1992:12). She is also the only researcher to describe the details of her procedures in sufficient detail as to make her study replicable. Therefore, the methods developed in this thesis rely heavily on her research.

Within the last few years more researchers have begun investigating utility indices which has resulted in the creation of indices for many new species. This is especially true with respect to marine mammals. Indices have been developed in the past few years focusing on phocid seals (Lyman *et al.*, 1992), otariid seals (Savelle *et al.*, 1996), and harbour porpoises (Savelle & Frieson, 1996). The construction of these indices varies little and follows similar methods. All of these studies, however, are limited to meat weight and gross weight analysis since, unlike land mammals, marine mammal long bones are full of trabecular bone and are not often seen broken at archaeological sites or in ethnographic studies. Savelle and Frieson (1996) present a good cross species comparison of the utility of the various marine mammals.

Another recent investigation has developed indices for horses (Outram & Rowley-Conwy, 1998). Outram and Rowley-Conwy (1998) examined three horses (two females and one male) and, following Binford (1978) and Metcalfe and Jones (1988), developed a meat utility index, marrow index, general utility index, and food utility index. Indices for each animal were developed and averaged in order to attain one overall index for horses. They compared and contrasted this index with that developed by Binford (1978) for caribou. They also compared marrow cavity volumes for their horse, Binford's caribou, and Blumenschine and Madrigal's (1993) wet marrow weight for zebra.

Lastly, is Madrigal's (1999) investigation in which he defines meat utility indices based on data from three white-tailed deer. Unfortunately, he does not give a detailed account of these indices nor does he discuss his method of construction. This omission is understood, as the primary goal of his dissertation was to provide a comprehensive analysis of the faunal material from one particular archaeological site. His dissertation also includes marrow indices information on seven white-tailed deer presented in another paper (Madrigal & Capaldo, 1999). None of the deer used in the meat indices construction are the same as those used in the marrow construction making his data general at best. While basically well presented, there are some problems with using Madrigal's indices. His indices are not readily available for another researcher's use, are not truly comprehensive indices based upon the whole carcass, and do not investigate variation based upon sex, age, or season.

Marrow Only Investigations

One of the earliest long bone marrow yield studies was conducted by Blumenschine and Madrigal (1993) on East African ungulates. They used 27 different East African ungulates representing eight species. They assessed marrow weights and marrow fat percentages and investigated how both variables differed between long bones within species, as well as between species (Blumenschine & Madrigal, 1993). Even though this study only addresses partial carcass issues, it is very complete and has wide-ranging applications to paleoanthropological research.

Brink (1997) examined the fat content of leg bones in bison and its application to archaeology. Rather than developing marrow utility indices, he was concerned with developing marrow fat percentages for all the long bones of three Plains bison. The elements were ranked according to the amount of marrow fat present. The results of these studies were compared to both Binford's (1978) and Emerson's (1990) research. The results of the rankings are comparable to those found by Emerson.

Madrigal and Capaldo (1999) looked at marrow fat percentages and marrow yields for long bones of white-tailed deer. The only animals they used, however, were road kill and in poor condition. Consequently, they do not provide live weights of the animals and they were unable to correlate marrow fat with fat reserves represented in the main body. Their study involved the use of seven deer, only one of which was an adult. As part of the derivation of their indices they took into consideration butchering time using both metal knives and stone flakes. They concluded that marrow yield is unaffected by marrow fat percentages and, therefore, an animal in poor condition with little fat reserves will still yield the same amount of marrow as an animal in excellent condition. This demonstrates that a fallacy exists if marrow yields alone are used as a consideration of utility. However, since the nature of the sample prohibited them from making a comparison of age and sex, and also did not allow them to reference the marrow investigations with the rest of the carcass, there remains a need for an all-inclusive study of white-tailed deer utility.

Ethnographic and Archaeological Implications

As utility indices continue to be developed, they are being applied to more and more areas of anthropological investigation. There is much research investigating the accuracy of utility indices by applying them to modern hunter-gatherers to test interpretations of differential transport. Further, utility indices can be applied to archaeological sites as a method of interpreting remains and determining if transport can be separated from other factors, such as taphonomic processes.

Morrison (1997) applied Binford's (1978) marrow index to two archaeological sites in the western Canadian Arctic, the Rita-Claire site and the Bison Skull site. The Rita-Claire site has been interpreted as a habitation site. The Bison Skull site is divided into east and west locations and Bison Skull East appears to be a look-out/kill area, while Bison Skull West appears to be the bone bed, or main disposal area. Morrison found that the Rita-Claire habitation site had a greater frequency of fragmented bones than either of the Bison Skull locations. In running a Spearman's Rank Order Correlation between the percent minimum number of animal units (MAU) and marrow index at the various sites, Morrison found a significantly positive and high correlation at the Rita-Claire site, but negative correlations at the Bison Skull locations. However, while this would seem to indicate that "selection for marrow utility was a major factor conditioning the composition of this assemblage" there is a complication (Morrison, 1997:45). Lyman's (1984) work with bone density studies have shown that this correlation may be due to survivability rather then differential treatment. Morrison plotted the density values obtained by Lyman (1984) for white-tailed deer against the whole-bone index and again found a high correlation suggesting that "the high correlation between anatomical frequencies and the marrow index may be due to a high correlation with density" (Morrison, 1997: 46). This may be correct if the presence of the elements alone were being investigated. However, the high differences in fracturing between long bones at habitation versus kill sites, along with the frequency differences within habitation sites of fracturing between certain elements, indicates a definite contrast in bone marrow utilization based on marrow utility. Morrison (1997) looked further into the issue by investigating bone breaking points and came to the conclusion that they were in accordance with an overall pattern of marrow extraction at the Rita-Claire site, but not at the Bison Kill locations. He also examined bone grease differentials but found no significant correlation between the assemblage at either site.

Morrison (1997) also looked at Binford's (1978) modified general utility index (MGUI) to see if it could be used to interpret differential transport especially since there should be a disparity between bone found at a kill site verses a habitation site. Low utility parts should be present at the kill site, and high utility parts present at the habitation site. Unfortunately, in running a Spearman's Rank Order Correlation between the adult MAU and MGUI, he could find only consistently weak negative correlations for all three locations. Due to the strong correlation already established between bone density and frequency at the two sites, no information about transport one way or another can be obtained since the density correlation probably explains the negative correlation between frequency and the MGUI.

Other researchers also have tried to apply or test utility indices archaeologically or ethnographically. The majority have focused upon the Hadza and other modern hunter-gatherer groups (O'Connell *et al.*, 1990; Emerson, 1993; Bunn, 1993; Bartram, 1993; Jones 1993; Enloe, 1993). These studies focus on examining the material left behind by modern hunter-gatherers in various site situations to see if differential transport agrees with what utility indices suggest. In general it does, though carcass variability between and within taxa, poor animal condition, and age-related yield differences may affect the accuracy of this agreement. Overall, in the hunter-gatherer societies studied four factors most influence the variability of a site's bone composition — transportation constraints, processing costs, fat yield, and amount of consumption of an animal prior to the return to a base camp (Emerson, 1993).

Conclusion

Skeletal part frequency, meat estimation, and utility indices research has been extensive. However, there is room for improvement. First, better procedural description needs to be established so that future researchers develop comparable indices. Second, more can be learned about the animals being investigated by utilizing information and methods available from wildlife biology and animal science research. Lastly, while there has been an influx of new utility index development in the last few years, there is still room for development of utility indices of other larger mammals, such as white-tailed deer. This project tries to help meet those goals.

Chapter III

Wildlife and Animal Science Related Research

Introduction

While archaeological literature has addressed many of the aspects necessary to faunal analysis, there is still much information to be gained from the wildlife and animal science literature that has not yet been incorporated into archaeological research. These areas include biological variation within white-tailed deer; lipogenesis and fat mobilization of reserves and how these differ by age, sex, and seasonality; and lastly what variation exists between white-tailed deer and other deer species as well as other artiodactyls. The latter is important in order to address the question of whether the utility indices of one animal should or could be applied to other related animals.

Intraspecific Variation

According to Smith (1975) the live weight of a white-tailed deer is primarily determined by five factors — a)geographical location, b)age, c)sex, d)season of harvest, and e)population density and quality of forage. The geographic distribution of white-tailed deer is extensive, ranging from near-treeline in southern Canada to sub-equatorial South America and includes 30 recognized subspecies (Baker, 1984). The size of a white-tailed deer can be greatly affected by its geographical location, and live weights range from less than 50 lbs. (22.65 kg) in tropical insular habitats to more then 300 lbs. (135.9 kg) in northern latitudes (Baker, 1984). Age can affect size: deer reach their mature body weight at age four for females and age five for males. However, by one and a half years, does have usually gained 80 percent of their mature body weight whereas bucks have gained only 60 percent of theirs (Jacobson 1995). Sex can also be a determinant of size and as a rule, mature, non-pregnant does weigh 60 to 75 percent of what adult bucks weigh (Baker 1984). Season of harvest not only affects size, but the peak nutritional seasons are also different for each sex. Male white-tailed deer should have the highest fat reserves just before the breeding season, mid-fall, and the lowest reserves just after the breeding season, in mid-winter. Does have the highest reserves just prior to conception, early winter, and the lowest reserves near the end of the lactational period, early fall (Cothran *et al.*, 1987). Population density and quality of forage can affect deer in a different manner. Deer in the same season and roughly the same age can be very different if one has good quality nutrition and/or low competition for resources and the other has poor quality nutrition and/or high competition.

The most important factors influencing the results of the construction of utility indices are sex and seasonality. Actually the two are quite interrelated. Male and female deer have high fat reserves at different times mostly due to reproductive needs. Also, seasonality can be affected by geographical location since breeding seasons differ depending on latitude. According to Jacobson (1994) white-tailed deer along the equator can breed almost year round. In most of Canada rut peaks in October and November, but along the Gulf Coast from Mississippi through the Florida panhandle rut peaks in January and February, and in southwestern Florida it peaks around July and August (Jacobson 1994). Because of the high degree of variation based on geographical distribution, it is difficult to tell whether it is accurate to apply white-tailed deer utility indices from deer in one region to another. According to some wildlife biologists (Shrauder, 1984; Jacobson, 1994) the breeding season within the lower Appalachian region begins around late November or early December, and based upon a 200-day gestation period does should start dropping fawns around mid-June (Jacobson, 1994). Over the length of a pregnancy a doe's percentage of total body fat should decrease significantly (Cothran *et al.*, 1987). This is especially important information since the doe acquired for this project in March 1999 (040799-1) was pregnant with twins at the time of her death.

Fat Indexes and Development

Many studies have been conducted to look at the fat reserves of both white-tailed deer and other cervids. The most frequently used method of obtaining information about an animal's health in wildlife studies is through kidney fat index (KFI) assessment. The relationship between the KFI and percent of body fat has been established mathematically for numerous white-tailed deer populations (Johns *et al.*, 1984). According to wildlife biologists, fat reserves are catabolized in an ordered, sequential, manner and long bone marrow fat is one of the last reserves to be assimilated by white-tailed deer. Also, femur fat is not expected to decrease substantially until the KFI drops below 30 percent (Harris, 1945; Riney, 1955; Dauphine, 1971; Ransom, 1965; Warren & Kirkpatrick, 1982; Warren & Krysl, 1983). This relationship has been demonstrated numerous times.

This raises an important question concerning the order of formation and catabolization of fat reserves in white-tailed deer. Lipogenesis is the metabolic process of producing and storing fat reserves. White-tailed deer begin lipogenesis in the fall and it is such a necessary process that some food needed for present survival may be turned into fat instead, placing the animal in a negative energy balance (Price & White, 1985). The sequential order in which these reserves are then utilized was first established by Harris (1945). Fat reserves disappear first from the rump, second from the subcutaneous areas, third from around the viscera, and lastly from the marrow cavities (Harris, 1945; Franzmann 1985). Furthermore, dissimilar rates of marrow fat mobilization among leg bones have been noticed among white-tailed deer. Femur, humerus, tibia, and radius marrow fat is mobilized at similar rates with the femur and humerus slightly ahead of the tibia and radius. But the metacarpus and metatarsus marrow fat levels may remain high even when femur fat levels are less then 30 percent (Fuller *et al.*, 1986). Males build up their highest reserves just prior to the breeding season and then are fairly depleted shortly after breeding season, in midwinter. Does build up their highest reserves just prior to conception and have used up most of their reserves by the end of the lactational period (Cothran *et al.* 1987).

There are at least six methods of determining the marrow fat percentages in long bones. They are ether extraction, visual estimation, compression, oven drying, reagent-dry assay, and freeze drying (Davis *et al.*, 1987). Davis *et al.* (1987) have critiqued these methods. They feel that ether extraction is reliable but tedious, expensive, and potentially dangerous. Visual estimation is subjective and therefore, limited. Hunt (1979), in examining the methods for calculating elk femur marrow fat, states that the compression method is only accurate for broad intervals of fat content. Davis *et al.* (1987) feel that all the drying methods are fast, efficient, and reliable. Hunt (1979) compared the three drying methods and achieved similar results with each. In this research ether extraction was conducted on the femur marrow of the two male deer in the study (112097-1 and 112097-2) by the animal science department at the University of Tennessee. They were willing to run only limited samples due to cost and time availability. The results were similar to those gained by the reagent-dry method which was conducted on all the long bones. In addition, visual analysis was used to support this data and for this I followed Cheatum (1949).

Cheatum (1949) examined the marrow from femora of deer in several stages of physical condition. Using alcohol-ether extraction and percentages from fresh and dry marrow weights he established a visual scale. He noticed that there was a correlation between "progressive reddening of the marrow core and diminished fat content" (Cheatum, 1949:19). However, he noted that there may still be a yellowing present with low fat content and that this could be a sign of anemia. He also noticed that the texture of the marrow changed as the fat content lowered. If high fat levels are present, the marrow should be solid with a waxy feel, and if low levels are present the marrow may be gelatinous. This method is good for getting relative ideas of condition but can produce no real quantitative data.

Verme and Holland (1973) developed a technique called the reagent-dry assay method for gathering quantitative data to express marrow fat levels. Their method involves using a mixture of chloroform and methanol called Bloor's reagent to break up and mix with the fat allowing the methanol to bond with the water and evaporate out leaving just the fat behind. Percentages based upon the before and after weight of the marrow examined can then be used for marrow fat analysis. Verme and Holland (1927) found their method to be an accurate estimate of bone marrow condition when compared to others.

Interspecific Variation

There may be a temptation to apply utility indices to closely related animals. Therefore, some investigation of interspecific variation is necessary to discern if this is really feasible or not. There is evidence to suggest that different species of deer catabolize marrow fat reserves in different sequential orders. Caribou marrow fat reserves mobilize differently from white-tailed deer marrow fat reserves. The proximal bones, femur and humerus, are mobilized first and are drawn on at similar rates. However, unlike white-tailed deer, there are no significant differences between the distal bones, tibia and metatarsus or radius and metacarpus. Like white-tailed deer, there are no meaningful differences in hind limb versus forelimb mobilization (Davis *et al.,* 1987). Moose, on the other hand, mobilize marrow fat proximally to distally similar to that of caribou, yet the distal bones of the hind limb (tibia and metatarsus) contain less fat then the corresponding bones of the front limb (radius and metacarpus) (Davis *et al.,* 1987; Peterson *et al.,* 1982). European roe deer, remarkably, metabolize fat reserves in the same manner as white-tailed deer, proximally to distally, with similar rates for the hindlimb as forelimb, progressing downward with the femur and humerus depleted first, then the tibia and radius, and last the metapodials (Ratliffe, 1980).

Similar interspecies differences of marrow fat metabolization has been noticed among African ungulates (Brooks *et al.*, 1977). Brooks *et al.* (1977) found that impala use fat reserves in the front and hind limbs at similar rates with the humerus and femur depleted first. However, the metacarpus and metatarsus will be depleted next and only after their levels drop significantly will the reserves in the radius and tibia be pulled upon. Reedbucks and kudus seem to follow similar patterns with marrow fat being catabolized proximally to distally, yet with the front limb slightly ahead of the hind limb. Buffalo fat mobilization is highly variable and mostly follows a pattern of proximal to distal depletion. However, sometimes the radius has less fat than the metacarpus and at other times more. It also appears that as the animal gets seriously stressed, reserves are pulled from the front leg before the back. The data Brooks *et al.* (1977) acquired on the nyala and eland appear to show no distinct pattern of fat mobilization in the long bones.

Besides marrow fat mobilization there are other large differences between cervids and other artiodactyls, such as bovids. Drew (1985), in a study examining meat production from farmed deer, compared white-tailed deer muscle groupings with cattle. He reports that "muscle groupings in the hind leg and saddle areas are proportionately 8 - 23% heavier in deer than the same muscle groupings in cattle, while muscles around the rib cage and shoulder are less well developed in the deer" (Drew, 1985:286). Figure 3.1 demonstrates where these differences occur. Each part represented is a ratio of that part's ranking on a deer compared to a standard of 100 for that part on cattle. For example, based on overall body ratios the shoulder of a deer makes up 86% of what the shoulder of

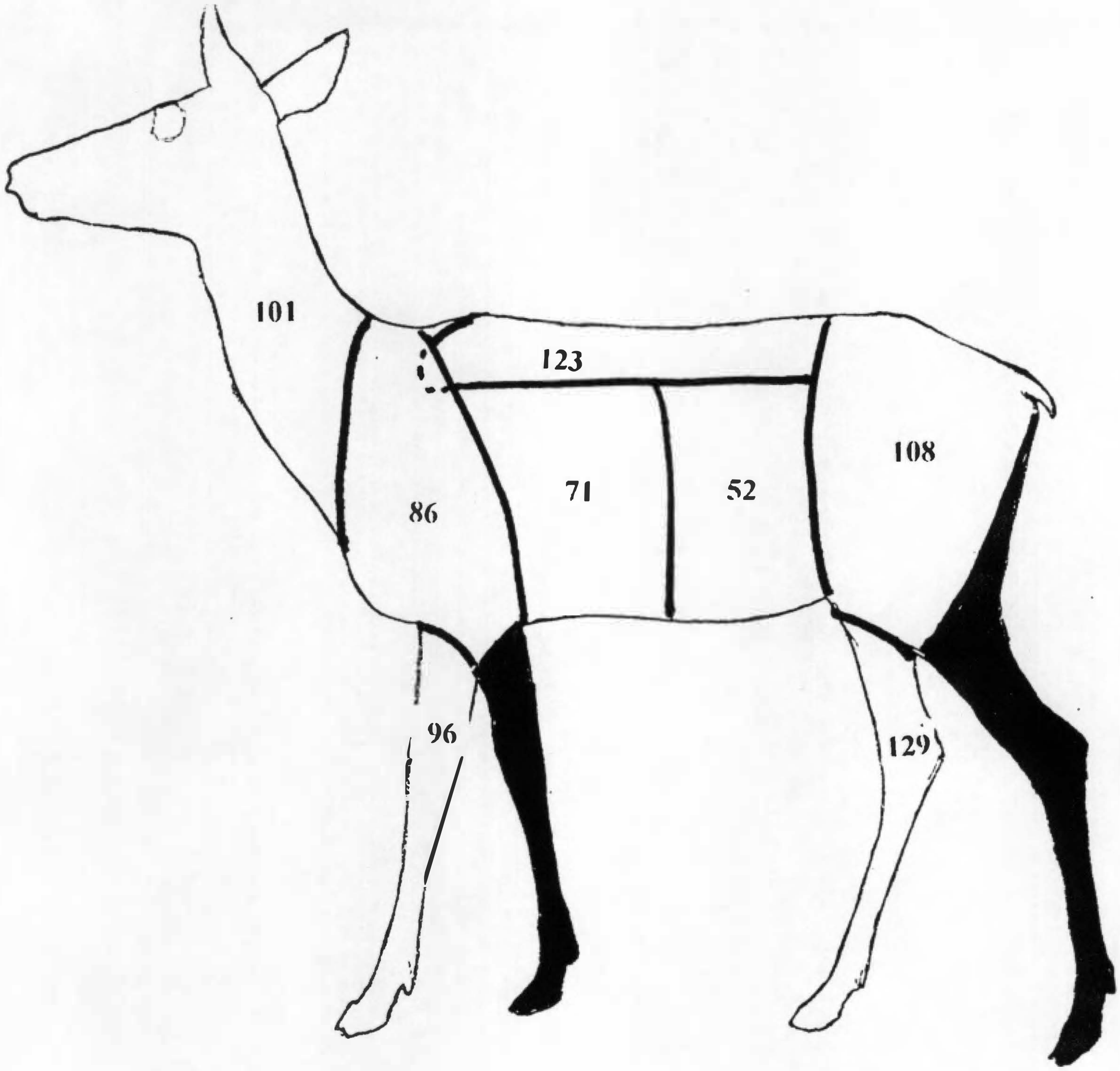

Figure 3.1 - Percentage of Total Muscle of White-tailed Deer in Each Group Relative to the Same Group in Cattle = 100. Adapted from Drew (1985:286:Figure 2).

a cow does, or 14% less. Yet, the back strap area is 123% that of a cow. Therefore, the meat distribution ratios clearly demonstrate the differences between artiodactyls.

Summary

In summary, wildlife and animal science data shows that enough differences exist between closely related species that utility indices for one should not be applied to another. This data supports the need for the development of utility indices for as many larger mammals as possible in order to interpret faunal remains from archaeological sites. Further research presented in chapter V supports this premise.

Chapter IV

Methods and Materials

Introduction

There are two main parts to this thesis — the construction of meat and marrow utility indices, and the investigation into the relationship between marrow fat percentages of the various long bones. Previous investigations into utility indices with other animals were reviewed in order to establish comparable methods and procedures. However, most previous researchers provide little or no details concerning their methods. Because Emerson (1990) seems to have the most rigorous and detailed procedures, her work with bison is drawn upon heavily.

Before starting research into white-tailed deer utility indices, a pilot of the procedures and methods was made with a pregnant, adult, female sheep (*Ovis aries*). This made it possible to see the problems associated with this type of analysis beforehand, and to allow for either correction and/or modification of the procedures.

Sample Size

The selection of the sample size was unfortunately strongly limited by time and availability of animals. Due to the nature of the project, the deer acquired needed to be in excellent condition, lacking no parts, and with almost no dessication having occurred. This greatly restricts or eliminates using road kill animals. Other methods of animal acquisition include deer made available by hunting season and wildlife studies. Hunters are reluctant to give up their whole prey for scientific study. This primarily left confiscated poached deer, animals killed due to wildlife research, and fresh and relatively undamaged road kill as research sources.

Sample size has been a concern to all previous researchers (Lyman 1994). The largest number of one species analyzed in any manner has been seven (Madrigal & Capaldo, 1999), but that study only looked at long bone marrow; the largest number analyzed utilizing whole carcasses is four (Emerson, 1990; O'Connell & Marshall, 1993). Obviously it is difficult to tell much about an entire population of one species based on so few animals. Lyman (1994) feels that indices based on these small sample sizes

> (a) mute individual variation such as that displayed by individuals of different age, sex, and nutritional status (typically correlated with season), not to mention inter-population variation, and (b) are not average values for the complete range of variation that different individuals of a taxon may display because few individuals have been measured (Lyman, 1994:231).

This particular study uses only five animals, four retrieved in mid to late fall and one retrieved in the spring. Therefore, with such limited retrieval opportunities suppositions made about variation are fallible but necessary.

According to Smith (1975) the live weight of a white-tailed deer is primarily determined by five factors — geographical location, age, sex, seasonality of harvest, and population density and quality of forage. These factors were controlled for as much as possible. First, the geographic area was limited to the ridge and valley region (Fenneman, 1938) of East Tennessee, which should control for population density and quality of forage. Three deer were acquired from Sequoyah State Park near Vonore, Monroe County, Tennessee by agents of the Tennessee Wildlife Resource Agency (TWRA) who were conducting a wildlife quality study between mid-October and November of 1997. The three deer included an adult 3 ½ year-old male (112097-1) , an adult 6 ½ year-old female (101597-1) and a juvenile 6 month-old male (112097-2). In November of 1998 another adult doe (112798-1) aged two and a half was illegally poached in Union County off highway 61 West. It was confiscated by a TWRA agent and donated to the University of Tennessee. In March of 1999 another adult doe (040799-1), approximately 3 years old, was hit by a car on highway 170 in Union County, picked up by TWRA, and donated to the University of Tennessee. The main focus of this thesis is on the four deer acquired all in mid-to-late fall. The deer collected in the spring is used as an outlier. Questions of age and sex were addressed by looking at differences between the adult male and the two adult females collected in the same season and by looking at the differences between the three adults and the one juvenile. Seasonal variation is addressed by comparing the nearly same age does found in different seasons. These deer are listed in Table 4.1.

Partitioning the Animal

One of the main criticisms of utility indices has been the lack of operationalization of the procedures (Metcalfe & Jones, 1988). There are questions concerning where the meat is cut and how the divisions are made. Due to individual animal variation, some of the cuts may differ slightly. Also, it is difficult to know exactly how an animal was butchered by past groups as some groups probably used different methods than others (Binford, 1978; Lyman, 1992). Emerson (1990) is clear about where her divisions were made, and these serve as a guide here. These division points are further supported by

Table 4.1 - White-tailed Deer Reference Numbers, Dates of Acquisition, Sex, Age, and Weights at Death

Reference Number	Date of Acquisition	Sex	Age	Weight at Death (kg)
101597-1	10/15/97	Female	6.5 yrs	41.761
112097-1	11/20/97	Male	3.5 yrs	57.875
112097-2	11/20/97	Male	6 mths	24.057
112798-1	11/28/98	Female	2.5 yrs	43.182
040799-1	4/7/99	Female	3 yrs	45.392

some archaeological evidence of butchering techniques based on cut marks (Guilday, Parmalee, & Tanner, 1962). Therefore, I have tried to present the process involved in as detailed a manner as possible.

There are some differences between this and previous work. All the marrow from a long bone will stay associated with that long bone, as well as all the meat associated with that bone. This investigation does not make divisions of proximal versus distal, or account for "riders." Another difference between Emerson's methods (1990) and the methods used here is that she separated inter-muscular fat from muscle and tendons and weighed it separately. This is easy to do for bison but not for an animal as naturally lean as a white-tailed deer, especially a southeastern white-tailed deer, and was not done here.

Cutting

First, while the animal is still fresh it is necessary to skin it and weigh the hide. The animal should then be gutted and the internal organs, minus the kidneys, weighed. The internal organs cannot be directly linked to any particular bone and are, therefore, of little use for the development of utility indices as a means of interpreting skeletal part frequencies in the archaeological record. The tongue, however, can be linked with the mandible and the kidney is useful to determine internal body fat reserves. Therefore, all the internal organs except these are discarded. The kidneys are weighed and the kidney fat index (KFI) calculated. This is useful later when doing the bone marrow analysis. Next the animal is subdivided into smaller parts which are individually weighed and then frozen. These divisions primarily follow Emerson (1990). The first of these is the skull and mandible. The next groupings are cervical vertebrae, thoracic vertebrae and ribs, lumbar vertebrae, and the innominates and sacrum. The femur through the phalanges (femur, tibia, calcaneus, astragalus, metatarsal, and phalanges) comprise a single unit; the scapula through the phalanges (scapula, humerus, radius, ulna, carpals, metacarpal, and phalanges) comprise another. Each group is weighed and then frozen. Weighing before freezing helps to account for blood loss after the sections are defrosted for further analysis.

The next step involves defrosting, weighing (to account for blood loss), and further dismembering each group (i.e. femur and tibia separated from the rest of the hind leg and weighed, then separated from each other and weighed). Once the sections are divided into groupings (cervical vertebrae, thoracic vertebrae, lumbar vertebrae, ribs, phalanges, etc.) or individual bones (femur, humerus, scapula, tibia, radius, etc.), they are weighed, all the meat removed, weighed again, the marrow removed, weighed again, and then boiled for grease removal and/or soaked in a three percent hydrogen peroxide solution or acetone for residual grease removal, and weighed again to get the dry weight of the bone. This bone weight is somewhat analogous to that which is found at an archaeological site.

Part of the goal of this project is to further establish the relationship between the kidney fat index (KFI) and the marrow fat percentage of the long bones in general, as well as the relationship of the marrow fat percentages amongst the individual long bones themselves. The KFI and marrow fat percentages have both been used by wildlife researchers as an indicator of the general health and quality of a deer (Warren & Krysl, 1983). The KFI is determined by dividing the weight of the kidney fat by the weight of the kidney and multiplying times 100 percent (Demarais & Jacobson, 1982). Therefore, the kidneys were weighed separately, the fat removed, and the kidney weighed again. The weight of the kidney fat was determined by subtracting the before and after weights. The KFI was then determined and recorded. This percentage is used and compared to long bone marrow fat percentages.

The analysis of the percent marrow fat in long bones is very useful for determining the body condition of deer. There are at least six methods of determining the marrow fat percentages in long bones. They are ether extraction, visual estimation, compression, oven drying, reagent-dry assay, and freeze drying (Davis *et al.*, 1987). Based upon a review of critiques (Chapter III) and accessibility by price and equipment availability, a combination of ether extraction, reagent-dry assay, and visual estimation was used for this study. Ether extraction was done on the femur marrow of the two male deer in the study (112097-1 and 112097-2). The results were similar to those of the reagent-dry method which was conducted on all the long bones.

In addition, following Cheatham (1949), visual analysis was used to support this data . As the marrow was removed its color and consistency for each individual long bone was examined. White coloring and a solid waxy consistency or greasy liquid consistency are indicative of high fat levels and good condition. A reddish color and more gelatinous texture represent less fat content.

Fat estimation using the reagent-dry assay method was determined by opening the long bone, removing a two to three gram plug from the center, weighing it, dehydrating it by the reagent-dry method (Verme & Holland, 1973), and then weighing it again. The material left should be primarily fat with an insignificant amount of minerals mixed in which is usually ignored by researchers (Franzman & Arneson, 1976; Snider, 1980; Davis *et al.*,1987; Ballard & Whitman, 1987).

Many wildlife biologists use the percent fat in the femur marrow of ungulates in northern areas as an indicator of nutritional status. They are of the opinion that while high fat levels may not always reflect good condition, low levels reflect poor condition (Bischoff, 1954; Franzmann & Arneson, 1976; Kistner *et al.*, 1980; Mech & Delguidice, 1985; Fuller *et al.*, 1986). If born out by this study, this could be useful for determining the health of the animals being consumed by people inhabiting a site. If, for instance, metapodials at a site are broken open by humans, yet other leg bones are not, this might be an indicator of environmental stress on the animal. However, application in this manner might only be useful for short-term habitation or kill sites as it would otherwise be difficult to associate bones of animals killed at the same time.

Once all the data has been collected, the actual construction of the indices can begin and the nutritional relationship between various parts can be analyzed. For the construction of the indices this project follows Metcalfe and Jones (1988) and Emerson (1990) both of whom use a simplified version of Binford's (1978) method for the construction of utility indices. As a last step a quantitative comparison of the animals by age, sex, and season must then be made of the various data in order to examine their influence on utility indices..

Meat Divisions

There has been much debate over where utility unit divisions are made. Therefore, presented in this section is a detailed description of where the cuts are made and what constitutes a unit. In actuality it was easiest to separate the forelimb first, then the hindlimb, then progress from cervical vertebrae back to caudal vertebrae.

The first division is to remove the head (skull and mandible) from the cervical vertebrae. The separation is made between the occipital condyles and the cranial articular cavities of the atlas vertebra. To do this, the head and neck are laid out along a straight line. Cuts are made upwards along the sagittal plane starting at the sternohyoideus muscle just behind the ascending ramus of the mandible. Cutting continues perpendicular to the neck into and through the brachiocephalus muscle, feeling with the knife to insert it between the occipital condyles and atlas, cutting the tendons connecting the two bones, as well as the spinal cord. The upward cut is continued along the sagittal plane ending just behind the nuchal crest.

Next, sequentially, it is best to separate the forelimb (scapula through phalanges) from the main body. This is probably the easiest division to make. By lifting the forelimb out away from the body it is possible to see some thin fatty tissue that is easy to cut through on the medial ventral side. Next, a cut is made transecting the rhomboideus and serratus ventralis muscles. They are cut under, almost all the way through, ending the cut along the upper dorsal edge of the scapular cartilage. Both forelimbs are separated in the same manner.

The next division is made between the last cervical (C7) and the first thoracic (T1) vertebra. It is necessary to feel along the animal and count down the vertebra estimating where C7 and T1 are located. Cutting is started along the rhomboideus muscle. Cuts are made dorsally to ventrally along the transverse plane down towards the manubrium, cutting where the sternohyoideus attaches to the manubrium. This divides out the cervical vertebrae into a group separate from the thoracic vertebrae and ribs.

The hindlimb (femur through phalanges) is better to separate while there is still some weight to the animal to keep it stable. While the forelimb division could be made while the animal is hanging or laying flat, it is definitely best to remove the hind limb while the animal is lying flat on its side with the lateral surface of the hindlimb facing up. It is necessary to feel along the superficial gluteals for the slight hard bulb that is an indicator of the greater trochanter. A slit is cut into the superficial gluteus, dorsal to the greater trochanter and parallel to the frontal plane, revealing the acetabulum and femur head. This is probably the most difficult division to replicate. First, the head and acetabulum are cut into and around, severing the connecting tendons until the femur head is free. Then the slit is continued slanting diagonally distal at about a negative 30 degree angle, cutting straight through all muscle both lateral and medial, bisecting the semimembranosus muscle. Once all muscle caudal of the trochanter has been cut through, the slit is then continued diagonally proximal to the trochanter at a positive 30 degree angle again cutting through both lateral and medial muscles and bisecting the tensor fasciae latae and semitendinosus muscles.

Next, the thoracic vertebrae were separated from the lumbar. Again it was necessary to feel along the skeleton locating the last thoracic (T13) and the first lumbar (L1). A cut was made dorsally to ventrally along the transverse plane at the division cutting into and through the serratus dorsatus caudalis and the obliquus internus abdominus. The cut was made straight down which left some of the obliquus externus abdominus with the lumbar section.

The last separation is made between the lumbar vertebrae (L6) and the pelvis-sacrum (S1). Once again it is necessary to discern where the lumbar ends and the sacral begins. This is difficult and quite frequently the last lumbar vertebra was removed with the sacral section. During meat removal, however, this inconsistency is accounted for and corrected. At the lumbar-sacrum division point the cut begins along a perpendicular plane to the vertebral articulation as done with the earlier vertebral separations. Cutting is made into the gluteus medias and down through the psoas minor and psoas major separating the lumbar and sacral sections.

Separating the ribs from the thoracic vertebrae also proved difficult and two different methods were utilized. With the first deer (101597-1) each rib was separated along with the sternum from the vertebrae, the ribs and sternum were weighed together and then the meat was removed. This was not very efficient. The next method employed proved to be much better and was utilized for the rest of the animals. Instead of weighing the bone, stripping the meat and weighing the bone again, the meat was cut from the rib and sternum area and weighed. The ribs and sternum were then removed and the meatless bone weighed. Lastly, the still fleshy thoracic vertebrae was weighed, the meat removed, and then the meatless bone weighed. Following butchery marks (Guilday, Parmalee, & Tanner, 1962), the meat within the first inch of the ribs on the ventral end was left as part of the thoracic vertebral section.

Individual divisions between the bones of the lower limbs are all made in a similar fashion. Cuts are made perpendicular to their articulations cutting through all muscle present. This is the best way to ensure that the individual bones are truly representative of utility regardless of where muscle connections occur, especially since butchering practices prehistorically differ group to group.

Once each division is made the sections or individual units are weighed. The meat is removed from each element with a standard filet knife. As much meat is cut away as possible though some tendons and muscle in hard to reach areas are stubborn and can not be removed. The meat free bone is then weighed. The long bones are also subjected to marrow cavity analysis.

Marrow Measurements

Each long bone is sawn just beside the trabecular bone of either end leaving the main shaft section free. The marrow is then pushed out, or in some cases it leaks out, of the main shaft and is weighed. The bone itself is also weighed after marrow removal. From the marrow plugs a two to three gram section is selected and placed in a jar. The jar with lid is weighed both before and after the plug is added. Following Verme and Holland (1973) the plug is then mixed with a 2:1 solution of 10 ml of chloroform and methanol, also known as Bloor's reagent. The containers used are 125 ml (4oz.) short widemouthed clear borosilicate glass vials with polypropylene teflon-lined closed-top caps to safely contain the mixture according to EPA Protocol B. A half mask respirator with an organic vapor/acid gases cartridge is worn while mixing and adding the chemical. The jars are left with their lids loose under a fume hood so the chloroform and methanol could evaporate. Chloroform is an excellent fat solvent and since methanol is hygroscopic it absorbs any water present in the marrow. Both chemicals volatize at room temperature and, therefore, evaporate out dehydrating the marrow (Verme & Holland, 1973). The material left is primarily fat with an insignificant amount of minerals usually ignored by researchers (Franzman & Arneson, 1976; Snider, 1980; Davis *et al.*,1987; Ballard & Whitman, 1987). The jars are weighed a few days later after all the solution is completely evaporated and from this the percent fat of each long bone can be figured. The weight of the jar is subtracted and then the after-weight of the marrow is divided by the before-weight and multiplied times 100 to get the percent fat of the long bone marrow.

In addition to the above methods, the marrow from the femora of the two male deer (112097-1 and 112097-2) were subjected to a proximate analysis conducted by the animal science department at the University of Tennessee. The results of this analysis agreed with the results of the marrow fat percentages.

Kidney Fat Index and Marrow Comparison

According to wildlife biologists, fat reserves are catabolized in an ordered sequential manner and long bone fat is one of the last reserves to be used by white-tailed deer. Also, femur fat is not expected to decrease substantially until the KFI drops below

30 percent (Harris, 1945; Riney, 1955; Dauphine, 1971; Ransom, 1965; Warren & Kirkpatrick, 1982; Warren & Krysl, 1983). Furthermore, dissimilar rates of marrow fat mobilization among leg bones have been noticed in white-tailed deer. Femur, humerus, tibia, and radius marrow fat is mobilized at similar rates with the femur and humerus slightly ahead of the tibia and radius; but the metacarpus and metatarsus marrow fat levels may remain high even when femur fat levels are less then 30 percent (Fuller *et al.*, 1986).

In Madrigal and Capaldo's (1999) study on white-tailed deer marrow yields, they looked at percent marrow fat content as well. However, they did not compare these percents to the KFI. Kidney fat indexes may provide an indication of how an animal's body would appear to a hunter. Did the animal have a good supply of stored fat in the main body and would that fat be enough nutritionally for the people consuming the animal? Also, it would be a tell-tale sign of which long bones would provide additional fat and whether the energy expenditure required in breaking open long bones or hauling additional carcass parts back to a camp would be worth the return. Therefore, the relationship between KFI and marrow fat percentages was examined in order to answer the following questions: Were the KFI's above or below the 30 percent that would affect marrow fat catabolization? Was the catabolization proceeding in the order predicted by wildlife research? How were these differences in fat percentages reflected by age, sex, and season? This information was also useful for other reasons. As noted in Chapter III, different species of deer catabolize marrow fat in different sequential orders. This information is particularly useful since some researchers might apply index values for one species to another. Borrero (1990) published a standardized meat and marrow index for guanaco using Binford's marrow values for caribou in conjunction with guanaco meat values to derive that index. The validity of this index is doubtful. Also, many researchers have applied the caribou index derived by Binford (1978) to white-tailed deer remains from prehistoric archaeological sites. These interpretations, while generally accurate and the best possible at the time, are not entirely reliable.

Chapter V

Results

Introduction

This thesis project aims to examine various components affecting white-tailed deer utilization. Below are the results of the meat, marrow, and full carcass utility indices for white-tailed deer. Variations between sex, age, and season for each index are also presented. The KFI was investigated and its relationship to long bone marrow fat percentages determined. The long bone marrow fat percentages were then compared with marrow utility. The utility indices are also compared to similar indices gathered for closely related species such as caribou (*Rangifer tarandus*) and sheep (*Ovis* sp.) as well as Madrigal's partial indices of white-tailed deer (Madrigal, 1999; Madrigal & Capaldo, 1999).

Meat Utility Index

The meat utility index was calculated by determining the weight of the whole unit, removing all the meat, and weighing the bone. The weight difference was considered to be the weight of the meat. The meat weight was divided by the weight of the skinned and gutted carcass, and the amount multiplied by 100 percent.

$$\frac{\text{Unit Weight of Meat}}{\text{Weight of Dressed Carcass}} \quad \text{X} \quad 100\% \quad = \quad \text{Meat Utility}$$

Meat utility was determined for all units of each of the five animals used in this study. Also, all the animals were averaged together for each unit to get one standardized meat utility index (SMUI). Results are listed in Table 5.1. The skull, mandibles, tarsals, and carpals were only considered for overall utility due to variations in the conduct of this project and difficulties concerning accurate meat removal. Early on the meat utility for these parts was seen to be low and accurate removal difficult so they were excluded from consideration. The first deer (101597-1) used in this project was brought in by the TWRA. The animal had already been gutted. As part of this process the tongue had been removed. Therefore, tongue weights were not used in this project though they were recorded for all the other animals (Table 5.2).

The meat yield for each unit was determined and averaged for the three females to get a standardized meat utility for the females (FMUI) which could be compared to the one adult male (MMUI) in the study. The two does of nearly the same age, one retrieved in the fall (112798-1) and one in the spring (040799-1), were compared to assess seasonal differences. The two near same-aged does were averaged (PFMUI) and compared with the 6 ½ year-old doe (OFMUI) to examine age differences. Also, all the adults killed in the fall (AMUI) were averaged and compared to the juvenile (JMUI) to examine age differences as well.

Table 5.1 - Meat Utility Index of White-tailed Deer by Individual and Averaged Standard Utility (SMUI)

	101597-1	112097-1	112097-2	112798-1	040799-1	SMUI
CV *	5.241	8.995	4.546	3.614	3.856	5.250
TV	6.909	9.659	6.367	4.617	7.883	7.087
RIB	6.341	14.316	8.358	7.888	8.453	9.071
LV	5.711	6.844	3.900	6.647	7.088	6.038
PS	11.256	8.777	8.645	8.273	6.589	8.708
SC	4.841	4.256	5.505	4.530	5.312	4.889
HU	4.746	3.274	3.086	3.544	3.220	3.574
RA	2.002	1.532	1.748	1.828	2.226	1.867
MC	0.212	0.154	0.220	0.115	0.138	0.168
FE	12.324	10.849	14.111	9.752	15.964	12.600
TI	4.120	2.634	3.347	5.254	3.502	3.771
MT	0.336	0.170	0.226	0.211	0.238	0.236

* See Appendix A for all codes used in Tables and Figures

Table 5.2 - Tongue Weights of Individual White-tailed Deer

	112097-1	112097-2	112798-1	040799-1
Tongue Weight (g)	107.7	58.25	252.4	274.2

Meat Utility Differences

There were some definite trends noticed once all the data were retrieved and analyzed. White-tailed deer are amongst the top 5% for overall species variation (Smith & Rhodes, 1994), so these differences based upon such a small sample size cannot be considered absolute. In general, as shown in Table 5.1, certain parts of the skeleton tend to represent a higher utility for all the animals. However, there are many differences evident when sex and age are considered. For analysis purposes, parts were broken down into those representing high, middle, and low utility for comparison. High utility parts are those with meat utility greater than 8 percent of the dressed carcass weight. Middle utility parts are those with a meat utility greater than 4 percent but less than 8 percent. Low utility parts are those representing a meat utility of less than 4 percent. When comparing the FMUI to the MMUI, differences based upon sex are evident (Figure 5.1, Table 5.3). For the female, only the femur and pelvis-sacrum have high utility. The ribs, lumbar vertebrae, thoracic vertebrae, scapula, tibia, and cervical vertebrae fall into the middle utility category. Only the humerus, radius, metatarsal, and metacarpal are considered low utility. In contrast, the male has more parts that fall into a high utility category. They are the ribs, femur, thoracic vertebrae, cervical vertebrae, and pelvis-sacrum. The middle utility category consists of only the lumbar and scapula while the humerus, tibia, radius, metatarsal, and metacarpal are low.

Based upon meat only rankings, removal of all the limb bones except the femur before transport of the male would be beneficial. Consequently, only the lower limbs of a female should be removed before transport. If sexing is possible with remains from a site,

Table 5.3 - Sex Comparison of Meat Utility of White-tailed-Deer: Female Standard (FMUI) and Male Standard (MMUI)

	FMUI	MMUI
CV	4.327	8.995
TV	6.470	9.659
RIB	7.561	14.316
LV	6.482	6.844
PS	8.706	8.777
SC	4.894	4.256
HU	3.837	3.274
RA	2.019	1.532
MC	0.155	0.154
FE	12.680	10.849
TI	4.292	2.634
MT	0.262	0.170

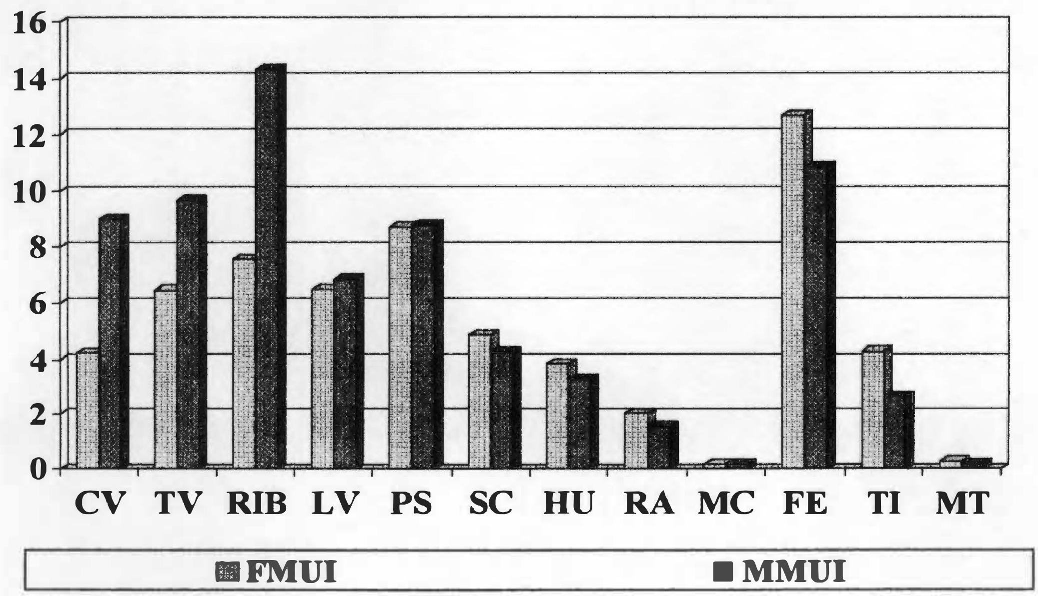

Figure 5.1 - Sex Comparison of Meat Utility of White-tailed Deer: Female Standard (FMUI) and Male Standard (MMUI)

it would be interesting to note if there are more female than male limb bones, especially tibias, present. Considering that males are typically heavier, if a male and female deer were equidistant from a habitation site when killed, in order to carry the carcass back it would be more practical to remove more parts from the male than from the female for transport. The adult male's axial region has a much greater utility when compared with the adult female's axial region, with the exception of the pelvis and sacrum. Conversely, the adult females' appendicular region has a much higher utility than that of the adult male.

When grouping the FMUI and MMUI into broader rankings of just high and low utility, the sex differences mostly disappear (Table 5.3). The parts were divided into high utility, those above six percent, and low utility, those below. Though in a different order, the general groupings for the two sexes are the same, except for the cervical vertebrae. They still represent high utility in males and low utility in females. High utility parts for both sexes are the femur, ribs, thoracic vertebrae, pelvis-sacrum, and lumbar vertebrae. Low utility parts for both sexes are the scapula, tibia, humerus, radius, metatarsal, and metacarpal.

When seasonal differences were examined for the two nearly same-aged does obtained in different seasons, the differences were not as marked as those between sexes, though some variation occurs (Table 5.1; Figure 5.2). The meat utility percents seem more dispersed in the fall doe (112798-1), with high and middle utility parts ranging from 4.530 to 9.752 for the seven parts falling into those categories. Meanwhile, the spring doe (040799-1) has only six parts in the high and middle categories ranging from 5.312 to

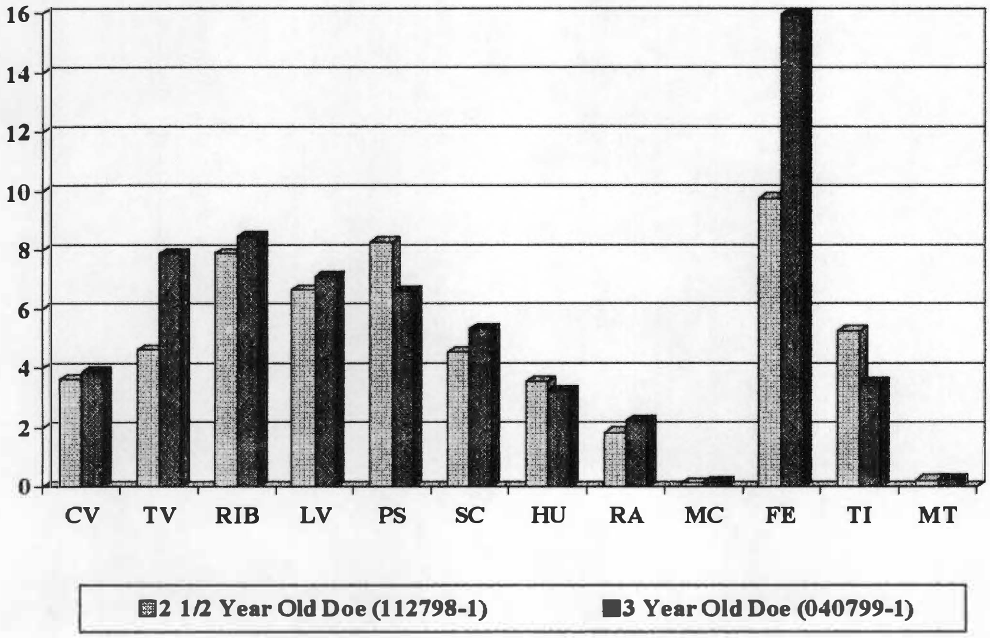

Figure 5.2 - Seasonal Comparison of Meat Utility of White-tailed Deer

15.964. In addition, aside from the immense utility of the femur, the spring doe's axial region has a higher concentration of important utility parts than the fall doe (Figure 5.2). When divided into just high and low utility parts, there are still differences. High utility parts for the spring deer are the femur, ribs, thoracic vertebrae, lumbar vertebrae, and pelvis-sacrum. For the fall deer the high utility parts are the femur, pelvis-sacrum, ribs, and lumbar vertebrae. The fall deer has fewer high-ranking parts.

In order to examine age differences the two does near in age were averaged (112798-1; 040799-1) and compared to the very mature 6 ½ year-old female (101597-1) (Table 5.4). In addition all the adult deer collected in the fall were averaged (101597-1; 112798-1; 112097-1) and compared to the one 6-month-old juvenile (112097-2) (Table 5.4). The differences between the young does in their prime and the older doe could be due to nutritional stress occurring with the older doe. However, how much effect age has on fat depletion and inability to rebound from stress is unknown. The 6 ½ year-old doe was killed in October at the end of the lactational period and may not have had a chance to recover whereas the 2 ½ year-old killed in November would have had an extra month of recovery. Overall, the main differences are seen when divided into high, middle, and low categories. The younger does have their concentration of meat in larger amounts around the femur and ribs. The 6 ½ year-old doe has high concentrations of meat in the femur as well as the pelvis-sacrum. Middle utility parts for the younger does are the pelvis-sacrum, lumbar vertebrae, thoracic vertebrae, scapula and tibia. Middle utility parts for the 6 ½ year-old doe are the thoracic vertebrae, ribs, lumbar vertebrae, cervical vertebrae, scapula, humerus, and tibia. Low utility parts for the younger does are cervical, humerus, radius,

Table 5.4 - Age Comparison of Meat Utility of White-tailed Deer: Prime Female Standard (PFMUI), Older Female Standard (OFMUI), Adult Standard (AMUI), and Juvenile Standard (JMUI)

	PFMUI	OFMUI	AMUI	JMUI
CV	3.735	5.241	5.950	4.546
TV	6.250	6.909	7.062	6.367
RIB	8.171	6.341	9.515	8.358
LV	6.868	5.711	6.401	3.900
PS	7.431	11.256	9.435	8.645
SC	4.921	4.841	4.542	5.505
HU	3.382	4.746	3.855	3.086
RA	2.027	2.002	1.787	1.748
MC	0.127	0.212	0.160	0.220
FE	12.858	12.324	10.975	14.111
TI	4.378	4.120	4.002	3.347
MT	0.225	0.336	0.239	0.226

metatarsal, and metacarpal. Low utility parts for the adult doe are the radius, metatarsal, and metacarpal. Therefore, it appears that the older doe has more higher utility parts then the younger does. However, when the data is graphically represented (Figure 5.3), the differences are insignificant.

When focusing upon age significance based on maturity, the fall adult deer average (AMUI) versus the one juvenile male (JMUI), more significant differences can be seen. High utility parts are the same for both – femur, pelvis-sacrum, and ribs. However, middle utility parts differ. For the adult deer (AMUI), parts of middle utility are the thoracic vertebrae, lumbar vertebrae, cervical vertebrae, scapula and tibia. Middle utility parts for the juvenile male are only the thoracic vertebrae, scapula, and cervical vertebrae. When examined graphically (Figure 5.4), the femur and the scapula of the juvenile represent much higher utility than that of the adults. Otherwise all the adult parts are higher in utility than the juvenile. These differences are probably due to developmental growth and the addition of muscle.

Marrow Utility Index

The marrow utility was determined by weighing the bone, sawing open the long bones, removing the marrow, and then weighing the bone again. The marrow was then weighed as well, but due to inconsistencies based upon marrow texture it appears the first method was the most accurate. Marrow that was more viscous would leak and an accurate measurement of the marrow weight could be erroneous with the loss too variable to be standard since marrow condition would vary bone to bone and animal to animal.

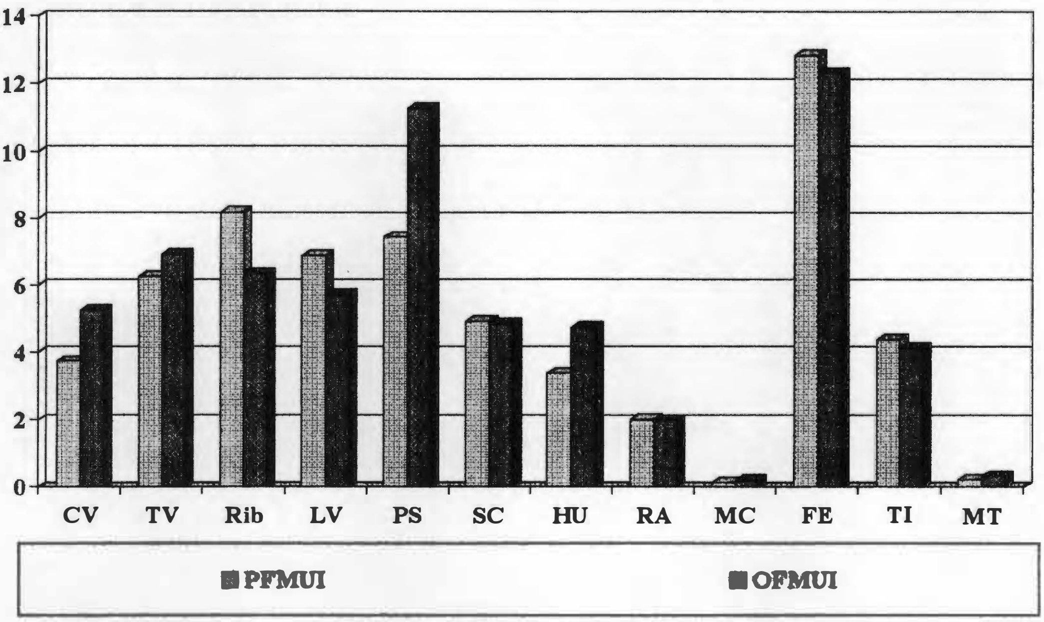

Figure 5.3 - Age Comparison of Meat Utility of White-tailed Deer: Prime Female Standard (PFMUI) and Older Female Standard (OFMUI)

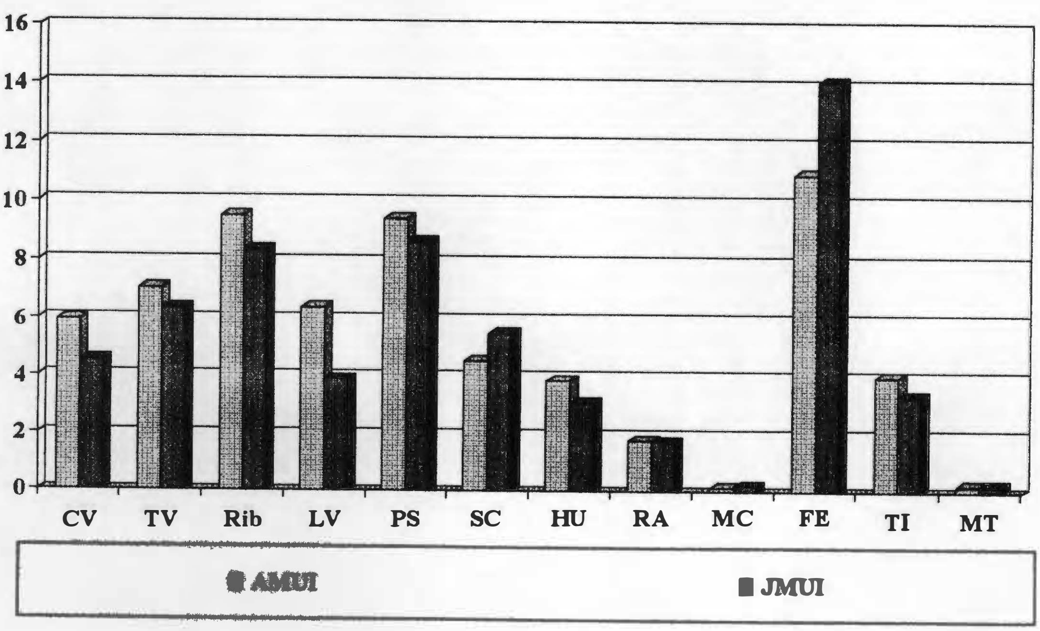

Figure 5.4 - Age Comparison of Meat Utility of White-tailed Deer: Adult Standard (AMUI) and Juvenile Standard (JMUI)

Some bone loss occurred due to sawing. However, since all the bones were sawed in a similar manner, variability should be minimal and measurements accurate. The marrow utility was determined by dividing the weight of the whole bone minus the weight of the bone without the marrow by the weight of the skinned and gutted carcass, multiplying it times two (since there are two of each element), and then multiplying the result times 100 percent.

$$\frac{\text{Whole Bone - Bone Without Marrow}}{\text{Weight of Dressed Carcass}} \quad x \quad 2 \quad X \quad 100\% \quad = \quad \text{Marrow Utility}$$

The marrow utility was determined for each of the five animals used in this study. All the animals were averaged together to get one standardized marrow utility index (SMAUI). Results are listed in Table 5.5. The elements examined included the humerus, radius-ulna, metacarpal, femur, tibia, and metatarsal. As with meat utility, standardization and analysis was made by averaging the marrow utility for the three females (FMAUI) to compare to the one adult male (MMAUI). Also, the two does of nearly the same age, but acquired in different seasons, were compared to determine seasonal variation. The adults killed in the fall were also averaged together (AMAUI) and compared to the one juvenile (JMAUI) to examine age differences.

Table 5.5 - Marrow Utility Index of White-tailed Deer by Individual and Averaged Standard Marrow Utility (SMAUI)

	101597-1	112097-1	112097-2	112798-1	040799-1	SMAUI
HU	0.0736	0.6460	0.0414	0.0704	0.0671	0.0634
RA	0.0694	0.0538	0.0574	0.0485	0.0453	0.0549
MC	0.0440	0.0230	0.0374	0.0280	0.0348	0.0334
FE	0.0962	0.1138	0.0918	0.0988	0.0932	0.0988
TI	0.2124	0.1166	0.1098	0.1095	0.1476	0.1392
MT	0.0766	0.0434	0.0846	0.0420	0.0522	0.0604

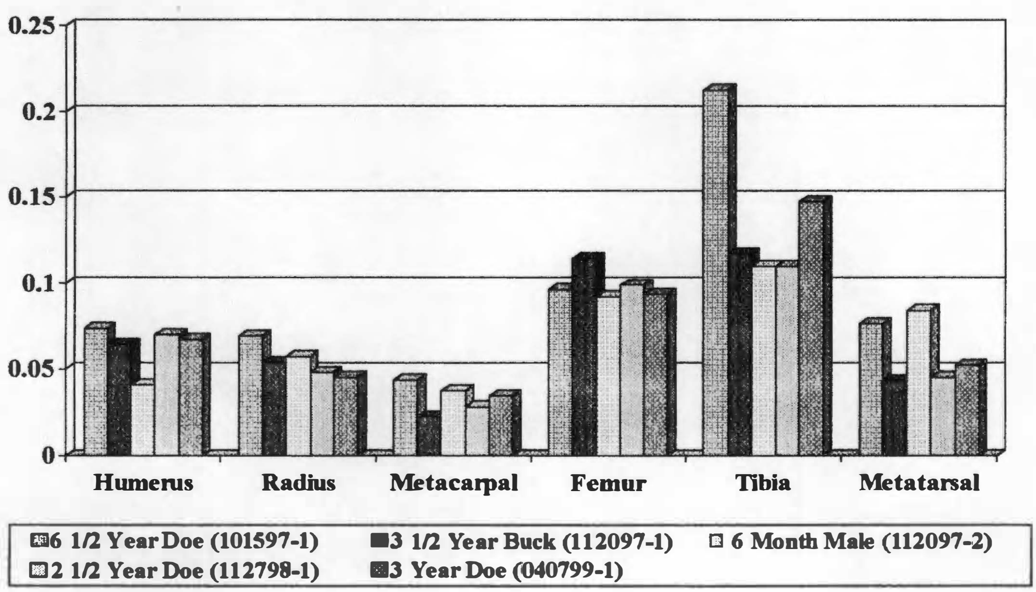

Figure 5.5 - Marrow Yield Percentage of Carcass Weight of White-tailed Deer

Marrow Utility Differences

When examined overall, the 6 ½ year-old doe (101597-1) appears to have the largest marrow utility (Table 5.5; Figure 5.5). This is curious since this deer was in the poorest physical condition based on its kidney fat index. The possible reasons for this are addressed in the section below where the results of the long bone marrow fat percentages are given. Comparison by season, sex, and age are given in Tables 5.5, 5.6, and 5.7. As can be seen, for marrow utility based upon marrow weight, the humerus and metacarpal have a slightly higher utility in females than males, but the tibia has a much higher utility in females than in males. The male femur has a slightly higher utility than that of the female. Marrow utility comparison of the fall adult deer and the juvenile acquired in fall shows some minor differences based on age. The adult humerus and tibia have higher utility than the juvenile, though the juvenile's metatarsal has higher utility than the adult. When looking at seasonal differences, the average of the fall deer marrow utilities is very similar to the single spring deer's utilities. Marrow weight does not appear to vary by season. This is reasonable since the marrow cavity volume does not change. However, marrow fat percentages could be underrated as a nutritional representation.

Long Bone Marrow Fat Percentages and the Kidney Fat Index

To judge the accuracy of the marrow utility index, long bone marrow fat percentages were also gauged for all the animals in the study. Long bones are not expected to have any marrow depletion until the KFI drops below 30 percent. This means that by viewing the interior fat reserves, a person could judge what kind of fat return

Table 5.6 - Age Comparison of Marrow Utility of White-tailed Deer: Adult Standard (AMAUI) and Juvenile Standard (JMAUI)

	AMAUI	JMAUI
HU	0.6950	0.0414
RA	0.0572	0.0574
MC	0.0316	0.0374
FE	0.1029	0.0918
TI	0.1462	0.1098
MT	0.0551	0.0846

Table 5.7 - Sex Comparison of Marrow Utility of White-tailed Deer: Female Standard (FMAUI) and Male Standard (MMAUI)

	FMAUI	MMAUI
HU	0.0703	0.6460
RA	0.0544	0.0538
MC	0.0356	0.0230
FE	0.0961	0.1138
TI	0.1565	0.1166
MT	0.0580	0.0434

Table 5.8 - Kidney Fat Index and Longbone Marrow Fat Percentages of Individual White-tailed Deer

	101597-1	112097-1	112097-2	112798-1	040799-1
KFI	10.65	59.54	43.64	48.41	35.26
HU	14.52	77.27	51.22	70.00	68.42
RA	7.46	93.33	88.37	85.71	87.50
MC	12.50	81.81	79.49	90.91	84.21
FE	22.73	82.61	*	82.76	75.86
TI	12.28	92.59	87.50	96.97	87.50
MT	9.52	82.05	86.54	91.30	93.55

* data missing

would be expected from the marrow of the various long bones and therefore, whether the energy expenditure of opening the bones would be worth the return. Upon investigation of the KFI's for all five animals in the study (Table 5.8), the 6 ½ year-old female (101597-1) is the only animal suffering serious stress where long bone marrow fat percentages should be affected. The pregnant doe acquired in the spring (040799-1) is approaching the 30 percent line so some effect of marrow fat depletion may be seen.

The long bone marrow fat percentage results are listed in Table 5.8. Even though the 6 ½ year-old doe (101597-1) had the highest utility based upon weight, her marrow fat percentages are severely depleted and any nutritional return would be the lowest for her of all five deer. The juvenile buck (112097-2) also exhibits lower percents, especially in his humerus. At his age, he should just be starting the switch from producing red-blood cells to storing fat, so this low number is expected even though the KFI is high. Unfortunately because of a mistake with the first trial of the long bone marrow fat percent procedure, the femur results are absent for the juvenile buck. The results were also lost for the older doe (101597-1) and the adult buck (112097-1) during this trial. However, their opposite side legs were available to run the test again. The two males had a plug removed from their opposite femurs to run a proximate analysis. Due to size variation, there was enough material left in the adult male's femur to run the long bone marrow fat percent again, but not enough marrow left in the button buck's femur. The proximate analysis shows a 73.96 percent marrow fat and 15.77 percent protein. The visual assessment (Cheatum, 1949) revealed a semisolid red marrow in keeping with these results. All the rest of the deer had above 30 percent KFI's and high long bone marrow fat percentages in correspondence with their KFI's.

Wildlife data suggest that both front and back legs should be depleted at similar rates and work proximally to distally (Fuller *et al.*, 1986). For the healthier animals this premise is true, though the radius and tibia seem to retain their fat levels longer than the literature suggests (Harris, 1945; Riney, 1955; Dauphine, 1971; Ransom, 1965; Warren & Kirkpatrick, 1982; Warren & Krysl, 1983). The marrow fat numbers for the 6 ½ year-old doe vary widely, but this could be a result of severe depletion.

Obviously, the marrow fat percentages contradict the marrow utility results, and therefore, marrow utilities based upon weight alone should not be used as they are an inaccurate predictor of the real nutritional return. Madrigal and Capaldo (1999) found similar results with their comparison of marrow utility and percent marrow fat.

General Utility Index

The general utility index (GUI) was developed to measure the total amount of nutritional return present in each individual animal unit. Basically once the meat and marrow have been removed, the remaining bone is cooked on simmer for roughly a week with the water being poured off and changed every one to two days. The bone is then soaked in hydrogen peroxide for 24 hours, left to dry, and then weighed. The GUI is determined by taking the original unit weight (before any meat removal) and subtracting the dry bone weight, dividing that total by the dressed carcass weight, and multiplying by 100 percent.

$$\frac{\text{Weight of Whole Unit - Weight of Dry Bone}}{\text{Weight of Dressed Carcass}} \quad X \quad 100\% \quad = \quad \text{General Utility}$$

The GUI was determined for each of the five animals in this study. All the animals were averaged together for all the units to get one standardized general utility index (SGUI). This information is presented in Table 5.9. Variation by age, sex, and season was then conducted in a similar manner as for the MUI and MAUI. The gross yield for each unit was determined and averaged for the three females to get a standardized general utility for the females (FGUI) which could be compared to the one adult male (MGUI) in the study. The two does of nearly the same age, but one obtained in the fall and one in the spring, were compared to assess seasonal differences. Also, the two near same-aged does were averaged and compared with the 6 ½ year-old doe to examine age differences. Lastly, all the adults killed in the fall were averaged and compared to the one juvenile in the study to examine age differences.

General Utility Differences

As with meat and marrow indices, some differences based upon sex, age, and season are evident when the overall yield is examined. When looking at sex differences, some obvious differences are noticeable (Table 5.10). The male has a cluster of high ($x>8\%$) and low utility ($x<4\%$) parts, but almost nothing that is middle ($8\%<x<4\%$). The male's scapula has a utility of 4.518 yet the next highest utility is the lumbar vertebrae at 7.209. The female average demonstrates a much more dispersed utility scale with five

Table 5.9 - General Utility Index of White-tailed Deer by Individual and Averaged Standard (SGUI)

	101597-1	112097-1	112097-2	112798-1	040799-1	SGUI
SK	3.167	2.237	3.584	1.804	2.145	2.587
MD	0.703	1.014	1.332	1.208	1.485	1.148
CV	6.170	9.938	5.534	4.754	5.166	6.312
TV	8.105	11.206	8.331	6.499	9.711	8.770
RIB	9.231	15.580	10.920	9.498	10.278	11.101
LV	6.158	7.209	5.493	7.222	8.285	6.873
PS	12.285	9.183	8.774	9.122	7.344	9.343
SC	5.173	4.518	5.843	4.851	5.722	5.221
HU	5.055	3.491	3.659	3.901	3.614	3.944
RA	2.153	1.714	2.182	2.102	2.498	2.130
MC	0.318	0.239	0.404	0.236	0.265	0.292
CA	0.089	0.027	0.107	0.055	0.075	0.071
FE	12.728	11.311	15.093	10.342	16.515	13.198
TI	4.824	2.914	4.117	5.663	3.965	4.297
MT	0.675	0.355	0.686	0.432	0.217	0.473
TA	0.273	0.125	0.342	0.187	0.443	0.274
PH	0.719	0.470	0.822	0.837	0.792	0.728

Table 5.10 - Sex Comparison of General Utility of White-tailed Deer: Female Standard (FGUI) and Male Standard (MGUI)

	FGUI	MGUI
SK	2.372	2.237
MD	1.132	1.014
CV	5.363	9.938
TV	8.105	11.206
RIB	9.669	15.580
LV	7.222	7.209
PS	9.584	9.183
SC	5.249	4.518
HU	4.190	3.491
RA	2.251	1.714
MC	0.273	0.239
CA	0.073	0.027
FE	13.045	11.311
TI	4.817	2.914
MT	0.441	0.355
TA	0.301	0.125
PH	0.783	0.470

middle utility parts at 4.190 (humerus), 4.817 (tibia), 5.249(scapula), 5.363 (cervical vertebrae), and 7.222 (lumbar vertebrae). When combined into more gross divisions of simply high (x>6%) and low utility (x<6%), the bone groupings are the same except for the cervical vertebrae which is high utility in males and low utility in females. This one exception is understandable since males need more muscle in their necks to support antlers and for neck protection during rut when fighting occurs.

Age differences between the prime-aged females (PFGUI) and the older female (OFGUI) are not very evident (Table 5.11). When grouped into high, middle, and low utility, the parts sort similarly with the humerus as the exception. It has a ranking of 5.055, therefore, middle utility, for the 6 ½ year-old doe (OFGUI). The young doe average (PFGUI), however, gives the humerus a low utility ranking of 3.758. Basically, the differences are not significant enough to be specifically assigned to age as a causal factor. However, when the fall adult GUI's (AGUI) are averaged and compared to the juvenile male (JGUI), there are noticeable differences (Table 5.11). The high utility parts are the same for both, and in the same order, but the adults have more parts which fall into middle utility rankings. Also, if the grosser division of only high versus low is made, none of the juvenile's middle utility parts move up into the high category. It still has only four high utility parts.

A comparison of the similarly aged does (112798-1 and 040799-1) from different seasons was made (Table 5.9). With two major exceptions the rankings are very similar. The pelvis-sacrum area of the fall doe has a higher utility than that of the spring doe: 9.122 compared with 7.344. However, the spring doe has a much higher utility ranking

Table 5.11 - Age Comparison of General Utility of White-tailed Deer: Prime Female Standard (PFGUI), Older Female Standard (OFGUI), Adult Standard (AGUI), and Juvenile Standard (JGUI)

	PFGUI	OFGUI	AGUI	JGUI
SK	1.975	3.167	2.393	3.584
MD	1.347	0.703	0.975	1.332
CV	4.960	6.170	6.954	5.534
TV	8.105	8.105	8.603	8.331
RIB	9.888	9.231	11.436	10.920
LV	7.754	6.158	6.863	5.493
PS	8.233	12.285	10.197	8.774
SC	5.287	5.173	4.847	5.843
HU	3.758	5.055	4.149	3.659
RA	2.300	2.153	1.990	2.182
MC	0.251	0.318	0.264	0.404
CA	0.065	0.089	0.057	0.107
FE	13.429	12.728	11.460	15.093
TI	4.814	4.824	4.467	4.117
MT	0.325	0.675	0.487	0.686
TA	0.315	0.273	0.195	0.342
PH	0.815	0.719	0.675	0.822

for the thoracic vertebrae than that of the fall doe: 9.711 compared with 6.499. This transposition in utility is quite interesting. As stated earlier in Chapter III, fat is catabolized in the body first from the rump, second from the subcutaneous areas, third from around the viscera, and lastly from the marrow cavities (Franzmann 1985). The spring doe (040799-1) has a lesser KFI, 35.26 percent, than the fall doe (112799-1), 48.41 percent, demonstrating that fat has already started to decline from around the viscera. It must also have started to deplete in the rump, or pelvis-sacrum, region. This could account for the difference and for the subsequent increase in utility importance of other regions. The depletion of body fat is most likely due to the stress of pregnancy. As stated in Chapter III, over the length of a pregnancy a doe's percentage of total body fat should decrease significantly (Cothran *et al.*, 1987). Therefore, if seasonality can affect the general utility index, these differences should be taken into account if applied to a site where seasonal occupation is suspected.

Lastly, by averaging the GUI's of all five deer used in the study, a standardized general utility index (SGUI) was developed (Table 5.9). Since determination of sex, age, and season may not be possible for archaeological material, it is necessary to have an all encompassing applicable model.

Summary of Utility Indices Development

While variation between adults of varying age is insignificant for all three indices (meat, marrow, and general), variation does exist between juveniles and adults and different indices should be applied to archaeological material representing those derivations. There are also some differences based upon sex. Generally, areas of the neck and chest have a slightly higher utility in males than in females, and the areas of pelvis and thigh have a higher utility in females than in males. However, adults have essentially the same high versus low utility parts when divided into the two coarse categories (high and low utility) instead of the more discriminating three (high, middle, and low utility). Also, between adult females there is variation between seasons due most likely to the stress of pregnancy. The examination of marrow utility indices and marrow fat percentages brings to light some fallacies of using indices based solely upon weight. Although a particular bone may have a higher utility based entirely upon weight, it does not necessarily have the highest nutritional return since the percent of fat can vary. Nonetheless, an element with a high marrow utility and a high marrow fat percentage would be of optimum use. Since the tibia appears to have the highest utility across the board, and an animal must be seriously depleted to lose fat reserves from that element, it can safely be said to be the long bone with the highest utility. Femurs consistently have a higher ranking than metatarsals when based upon weight. However, since the femur is more likely to lose fat reserves before the metatarsals, its utility based upon marrow weight (or volume) alone is overestimated.

Comparison with Other Indices

One of the other questions to be addressed by this project is whether or not utility indices from one species should be applied to another. In order to examine this, the SGUI developed for white-tailed deer was compared with that developed by Binford (1978) for both caribou and domestic sheep. In addition, since the caribou used by Binford is a prime-aged male around 3-5 years, it is compared to the male 3 ½ year-old (112099-1) white-tailed deer used in this project. A direct comparison with these findings for white-tailed deer to the partial indices developed by Madrigal (1999) would be ideal. However, his raw data is not accessible in a comparable form. Base rankings can be and are compared, though the data is qualitative and not quantitative.

When comparing white-tailed deer SGUI to Binford's (1978) MGUI for sheep, some differences are apparent (Table 5.12, Figure 5.6). First, the sheep's ribs have a much higher utility than that of the deer. However the deer lumbar vertebrae, femur, and tibia-tarsals have higher utility than that of sheep. Remarkably, the caribou and white-tailed deer seem to differ in more areas than the sheep and deer (Table 5.13, Figure 5.7). The white-tailed deer SGUI comparison with caribou show the caribou with slightly higher rib utility, but otherwise the deer parts outrank the caribou for utility, especially with significantly higher rankings for the thoracic vertebrae, lumbar vertebrae, pelvis-sacrum, and slightly higher rankings for the femur. When comparing the similar aged and sexed white-tailed deer to the caribou, even more extreme differences can be seen, and in this instance the ribs are similar in rankings. In addition to the thoracic vertebrae, lumbar vertebrae, and pelvis-sacrum having significantly higher utility in the 3 ½ year-old white-tailed deer than the caribou, the deer's cervical vertebrae also have a higher utility as well. Therefore, the appendicular skeleton has similar utility for the two species, but the axial skeleton of the deer carries a higher percentage of meat than that of the caribou. These results should help discourage researchers from applying utility indices from one species to another.

Table 5.12 - General Utiltiy Index Comparison between Sheep (Binford, 1978) and White-tailed Deer

	Binford (1978) Sheep 1	Binford (1978) Sheep 2	Deer SGUI
SK	2.72	4.64	2.59
MD	1.55	2.60	1.15
CV	8.56	7.41	6.31
TV	5.47	8.71	8.77
RIB	19.47	19.10	11.10
LV	2.70	4.31	6.87
PS	9.79	8.04	9.34
SC	4.78	4.18	5.22
HU	3.31	2.89	3.94
RA	1.83	1.61	2.13
MC/CA	0.74	0.66	0.36
FE	8.46	7.30	13.20
TI/TA	2.42	2.47	4.57
MT	1.20	0.74	0.47
PH	0.47	0.49	0.73

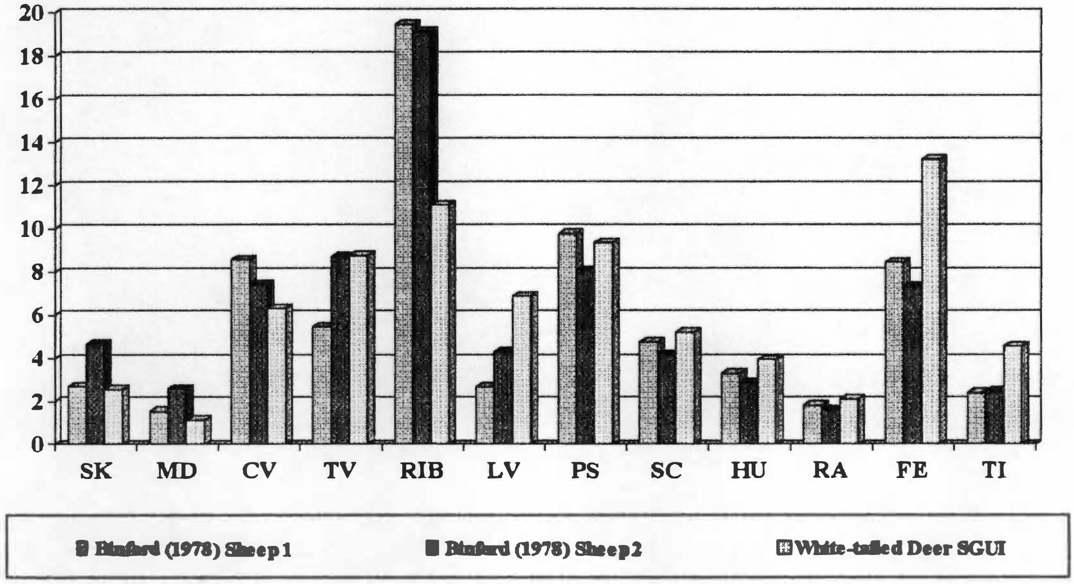

Figure 5.6 - Comparison between Sheep (Binford, 1978) and White-tailed Deer Standard General Utility Index (SGUI)

Table 5.13 - General Utility Index Comparison between Caribou (Binford, 1978) and White-tailed Deer

	Binford (1978) Caribou	Deer 3 1/2 Male(112097-1)	Deer SGUI
SK	2.80	3.584	2.587
MD	1.54	1.332	1.148
CV	5.50	5.534	6.312
TV	5.60	8.331	8.770
RIB	14.70	10.920	11.101
LV	3.90	5.493	6.873
PS	6.38	8.774	9.343
SC	4.82	5.843	5.221
HU	3.34	3.659	3.944
RA	1.84	2.182	2.130
MC/CA	0.75	0.511	0.363
FE	10.74	15.093	13.198
TI/TA	3.08	4.459	4.571
MT	1.51	0.686	0.473
PH	0.29	0.822	0.728

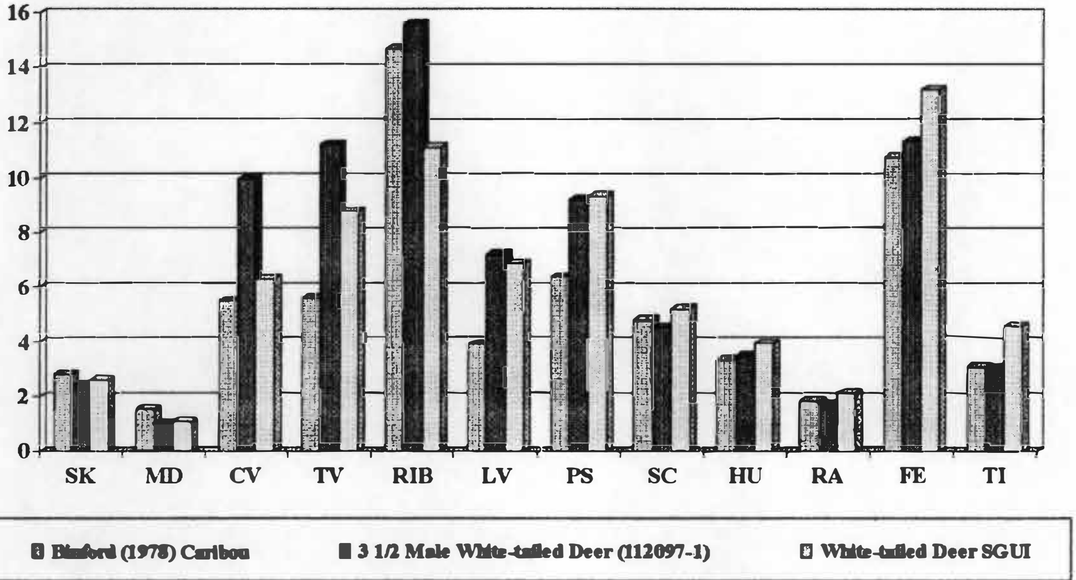

Figure 5.7 - Comparison between Caribou (Binford, 1978) and White-tailed Deer Male and Standard General Utility Index (SGUI)

Madrigal's (1999) work with white-tailed deer was also reviewed and compared with the one developed here. His qualitative rankings for marrow yields along with those from this study are presented in Table 5.14 and similar ranking comparisons for meat yields are presented in Table 5.15. His marrow yield rankings contrast slightly with those from this study, but the meat rankings contrast sharply. These differences may be explainable. The marrow ranking problem could be the result of having mostly juvenile individuals. Of the seven deer in Madrigal's (1999) study, only one was an adult. The majority of the deer represented in this study are adults. The differences in the meat ranking could be a problem of where cuts for divisions were made. As noted previously, detailed description of these divisions are not available.

Summary

The results of this study are a warning to the misapplication of utility indices. There are definitely significant enough differences between similar species to affect the accuracy of interpretation, if utility indices from one species are applied to another. In addition, though a partial index already exists for white-tailed deer, it is not inclusive enough for accurate interpretation of archaeological material, nor is it replicable. Contradicting results make the development of indices with detailed information about where divisions were made necessary.

Table 5.14 - Comparison of White-tailed Deer Standard Marrow Utility Rankings with Madrigal (1999) Marrow Rankings

Madrigal (1999) Marrow Rankings	Jacobson Marrow Rankings
Tibia	Tibia
Femur	Femur
Radius	Humerus
Metatarsal	Metatarsal
Humerus	Radius
Metacarpal	Metacarpal

Table 5.15 - Comparison of White-tailed Deer Standard Meat Utility Rankings with Madrigal (1999) Meat Rankings

Madrigal (1999) Meat Rankings	Jacobson Meat Rankings
Femur	Femur
Thoracic Vertebrae	Ribs-Sternum
Ribs-Sternum	Pelvis-Sacrum
Cervical Vertebrae	Thoracic Vertebrae
Scapula	Lumbar Vertebrae
Pelvis-Sacrum	Cervical Vertebrae
Tibia	Scapula
Humerus	Tibia
Lumbar Vertebrae	Humerus
Radius	Radius

Chapter VI

Application of Utility Indices: Westwood Plantation (16CT490)

Introduction

The data developed above are applied to white-tailed deer remains from Westwood Plantation Site (16CT490) in Catahoula Parish, Louisiana in order to establish the best methods of interpretation, and also to identify problems inherent to the application of these data. This site was chosen because of the large numbers of white-tailed deer bone recovered and the bone's excellent state of preservation. Westwood Plantation was established in 1844 and is located along the Tensas River 20 km upriver from its junction with the Ouachita and Little rivers. Both the preservation of the material and the meticulous recovery methods employed make the site's deer remains a good test for the application of utility indices developed here.

History of Westwood

Westwood Plantation (Hunter, 1997) was established by Henry Mandeville, an attorney born in Pennsylvania who moved to Natchez, Mississippi in 1835. Historic records indicate a difficult start for the plantation. The owners and workers were plagued by disease, partly caused by the swampy conditions which resulted in the death of Henry's wife, Julia. Despite this slow start, by 1860 Mandeville was considered one of the principal planters in the area. During the early years of the Civil War the family lived conservatively, but was not deprived, and "scarcely felt any inconvenience" (Hunter, 1997:3). In May 1863 the war finally came close to Westwood when Union gunboats were sent up the Ouachita River to attack Confederate batteries at Fort Beauregard in Harrisonburg. Near the end of the war supplies became difficult to acquire, and the Mandeville family suffered major setbacks. In 1865 all of Westwood's cows drowned in the spring floods. Loss of labor and bad conditions only became worse when floods in 1866 inundated the cotton gin, and spring flooding in 1867 ruined the planting. Records noted that the chickens were so stressed they would not lay eggs. By the end of the summer of 1871 conditions were desperate and the Mandeville's were considering leaving Westwood and moving to New Orleans. That year the corn crop matured but the hogs destroyed it before it could be harvested. The plantation was reduced to only one mule and two horses, not enough to put in late crops. In December 1871 Mandeville left Westwood, but died only one month later on January 25 in New Orleans. His son moved onto the plantation with his family until the main house burned in February 1873. Though not sold until 1904, there is no historical evidence of anyone occupying the site after 1873. Due to the numerous events of bad luck coupled with Union occupation of the area, a heavier reliance upon wild game than usual might be expected at this site (Hunter, 1997).

Archaeology of Westwood Plantation

The U. S. Army Corps of Engineers conducted Phase I investigations of 841.7 hectares for the Sicily Island Levee Project in 1995. During the investigations six sites were considered potentially acceptable for the National Register and were tested further to determine their exact significance. Westwood Plantation was found to be of significant historic value and mitigation was recommended since it would be impacted by the proposed levee construction. Testing in 1996 employed controlled surface collections, a remote sensing survey (magnetometer), and test units to evaluate the site's research potential. Material was screened using 1/4 inch and 1/8 inch mesh. Flotation samples were also taken and processed. Therefore, recovery of faunal material was optimum (Hunter, 1997; Hunter *et al.*, 1999).

Application of Utility Indices

Procedures for application of the indices were derived from Emerson's (1991) utility study with bison. She was very specific in detailing the techniques used. First, for application purposes and since bones representing evidence for age, sex, or season of death are either too fragmented for that kind of analysis or absent altogether in the material from Westwood, only the standardized general utility index (SGUI) model was developed and applied to the white-tailed deer. The procedures should work the same for any age, sex, and seasonal data presented. The model could also be developed based only upon meat or marrow utility if the researcher so desired. Once all the values were assessed for utility, the part with the highest ranking, in this case the femur, was given a value of 100%. The remaining utility elements were then divided by the original value of the femur (i.e., 13.198) and multiplied by 100%. These values are represented in Table 6.1. These values were then plotted across the y-axis of a simple scatter plot (Figure 6.1).

Table 6.1 - Standard General Utility Values (SGUI) and Modified Standard General Utility Percents (SGUI%) of White-tailed Deer from the Westwood Plantation (16CT490)

	SGUI	SGUI%
SK	2.587	19.6
MD	1.148	8.7
CV	6.312	47.8
TV	8.770	66.4
RIB	11.101	84.1
LV	6.873	52.0
PS	9.343	70.8
SC	5.221	39.6
HU	3.944	29.9
RA	2.130	16.1
MC	0.297	2.3
CA	0.071	0.5
FE	13.198	100.0
TI	4.297	32.6
MT	0.473	3.6
TA	0.274	2.1
PH	0.728	5.5

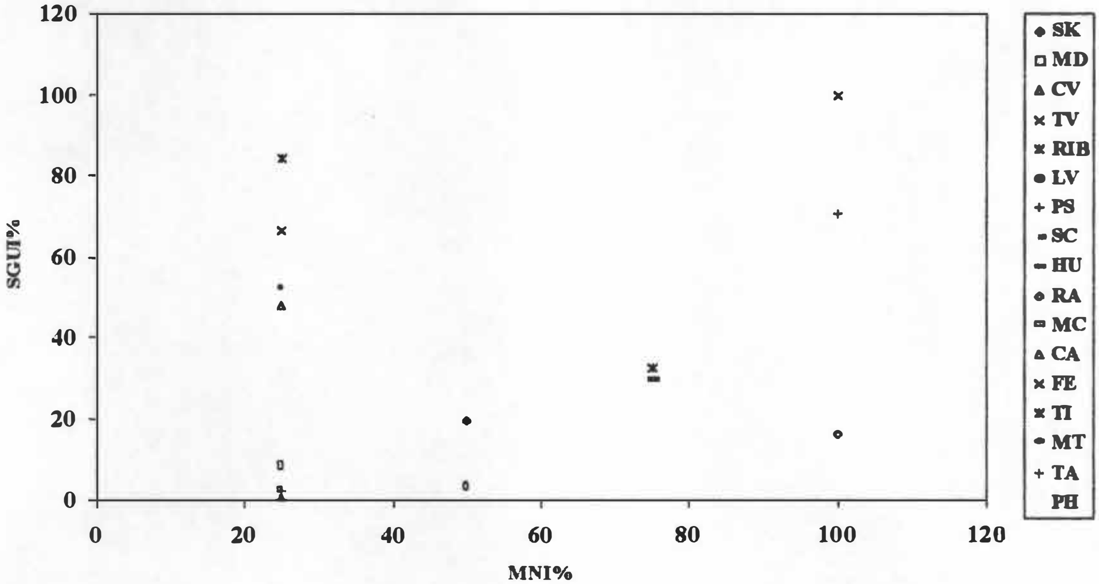

Figure 6.1 - Scatter plot of a Minimum Number of Individuals Per Skeletal Portion Percent (MNI%) of White-tailed Deer from Westwood Plantation (16CT490) and Standard General Utility Percents (SGUI%) of White-tailed Deer

The data from Westwood was plotted in a similar manner. First, the elements upon which the total MNI (minimum number of individuals) for the site was calculated are given a value of 100 percent (radius, femur, pelvis-sacrum). The next stage deviates slightly from that which Emerson (1991) employed. While she used MAU, a better representation is the MNI value per skeletal portion following White (1953). Therefore, each unit that represented a maximum MNI for the site, in this case an MNI of four, was given a value of 100 percent. Each of the elements that represented a lesser MNI per skeletal portion, such as three for the humerus, was then divided by the max-MNI (i.e., 4) and multiplied times 100 percent. These values for Westwood are represented in Table 6.2. These values were then plotted across the x-axis of a simple scatter plot for each of the utility units (Figure 6.1).

It is expected that these data should cluster in such a way to show representation of some form of utilization strategy. This is not the case. The data presented here do not produce a good curve or inverse curve correlation which would specify a particular utilization method – unbiased, bulk, or gourmet (Figure 6.2). The three strategy types, reproduced in Figure 6.2, are

> 1) the unbiased strategy, where carcass units are removed in direct relation to their utility, 2) the bulk strategy, where units of moderate and high value are removed in greater frequencies than parts of low value which are abandoned at high rates, and 3) the gourmet strategy, where units of high value are removed from the site in high frequencies and moderate and low utility units are abandoned at the site in increasing rates (Emerson, 1990:642).

There is also no linear arrangement which should occur if the material was collected in an unbiased manner. However, it is likely taphonomic factors have affected the sample.

Table 6.2 - Minimum Number of Individuals Per Skeletal Portion (MNI) of White-tailed Deer at Westwood Plantation (16CT490) and Minimum Number of Individual Percents (MNI%)

	MNI	MNI%
SK	2	50
MD	1	25
CV	1	25
TV	1	25
RIB	1	25
LV	1	25
PS	4	100
SC	3	75
HU	3	75
RA	4	100
MC	1	25
CA	1	25
FE	4	100
TI	3	75
MT	2	50
TA	1	25
PH	1	25

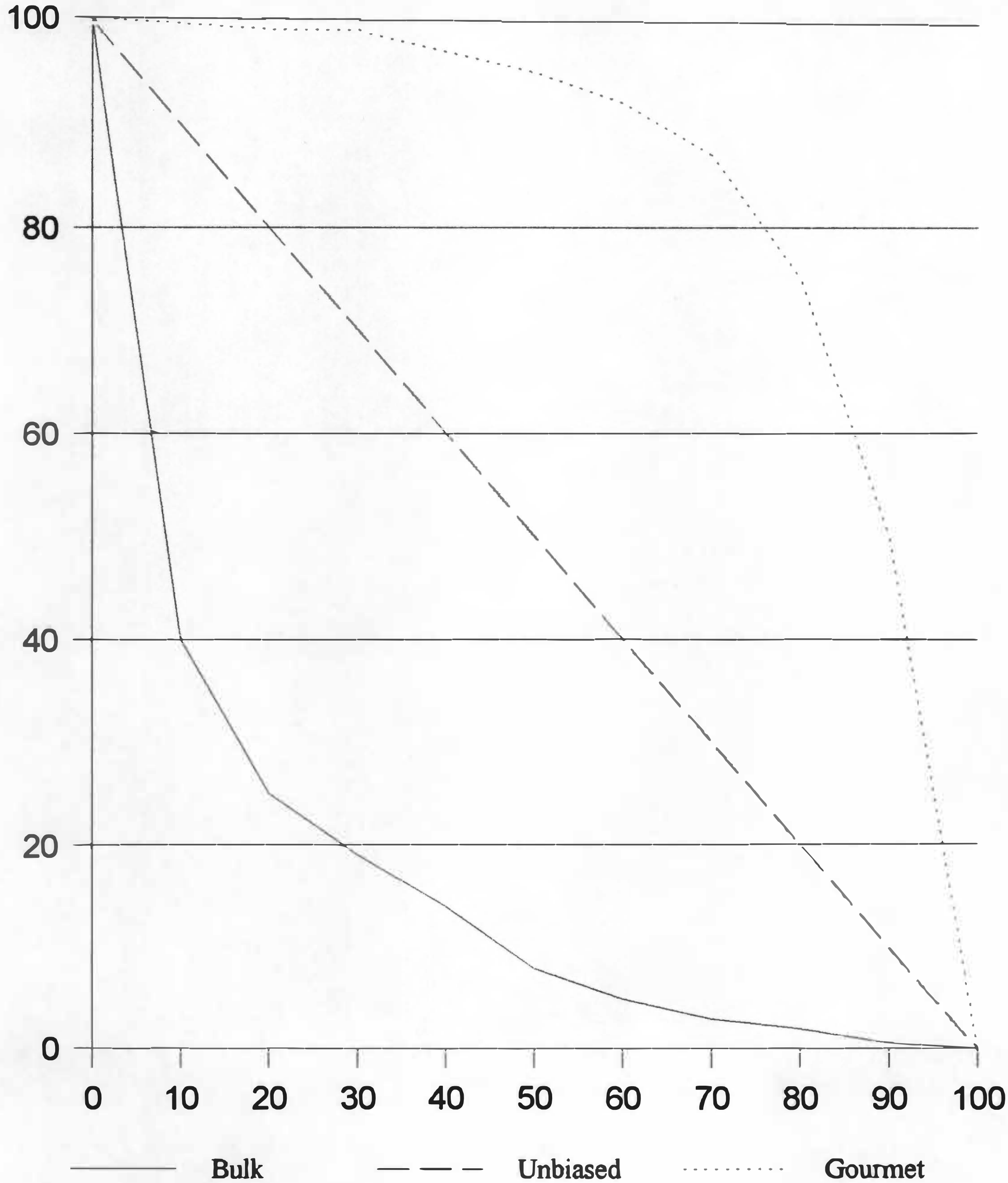

Figure 6.2 - Relationship Between Model Values and Percent MNI per Skeletal Portion for Assemblages with Different Carcass Unit Recovery Strategies. Redrawn from Binford (1978:81:Figure 2.18) and Emerson (1990:643:Figure 8.3)

Bones such as the vertebrae and ribs are less dense and less likely to survive even though they have a high utility, whereas bones such as the radius are more dense and likely to survive despite their low utility.

A scatter plot of the relationship between bone density and SGUI percent was plotted (Figure 6.3). This plot demonstrates how the distribution of elements from a site should look if both natural taphonomic processes and differential utility choice are occurring. The SGUI percent from above was plotted across the y-axis. The bone densities used were adapted from Lyman (1994). Only the highest bone density from the choice of scan sites for each element was listed. Following the same techniques used above, the element with the highest bone density was given a value of 100 percent and each of the other units were divided by that density and multiplied by 100 percent. This represents the survivability of the bone and those portions that should be present if the MNI per skeletal portion is the same ratio as that of bone density. Though the plot of MNI percent and SGUI percent does not cluster as nicely as the ideal, there is some clustering with two main outliers (Figure 6.3). Both the femur and the pelvis-sacrum have a higher representation than expected if both utility and taphonomic processes were acting upon the bone. In contrast, the metacarpal, mandible, carpals, and phalanges are under-represented for what they should be if both utility and taphonomic processes were occurring. These two discrepancies could be explained if higher than average numbers of deer femora and pelvis-sacrum parts, parts with high utility, were being brought back to the site, and less than average numbers of deer metacarpals, mandibles, carpals, and phalanges, low utility parts, were being transported. Such an interpretation suggests that

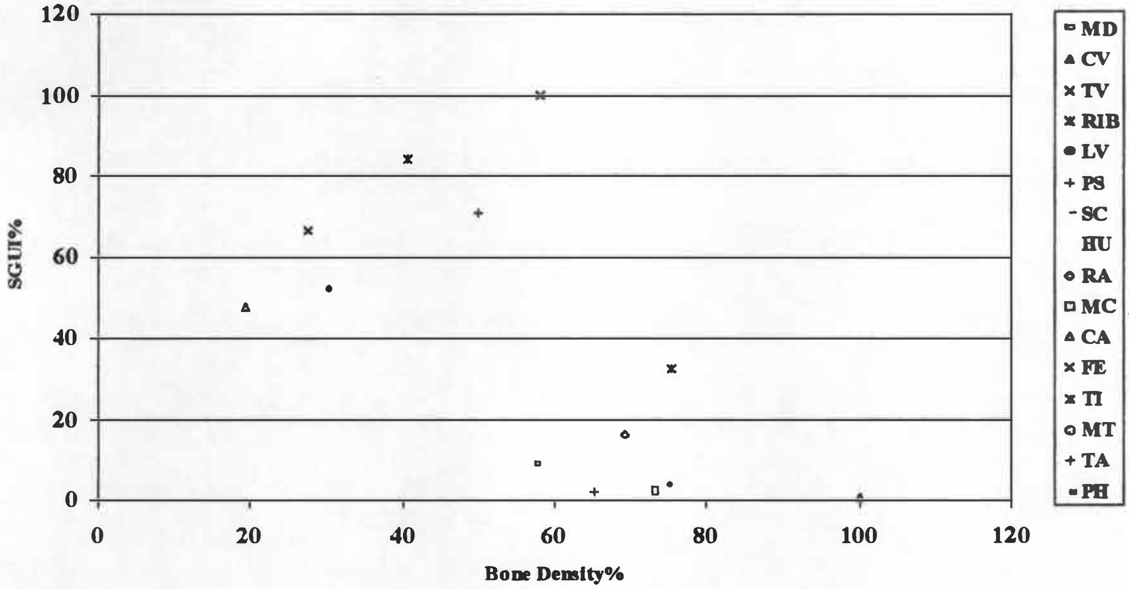

Figure 6.3 - Scatter plot of Standard General Utility Percents (SGUI%) and Bone Density Percents

some selection for white-tailed deer higher utility parts was occurring at the Westwood Plantation. Beauchamp (1993:80) states "if a single hunter has killed a prime-aged male, weighing as much as 200 pounds, it would be very difficult to drag the whole animal a long distance back to the home site. Thus, he might elect to carry meat packages of the upper fore- and hind-limbs, leaving cranial and lower limbs behind." Historical documentation suggests that Native Americans practiced differential transport (Fenton, 1978). If white-tailed deer were taken at some distance "the usual practice was to butcher the animals on the kill site and haul back only the most edible parts" (McCabe & McCabe, 1984:29).

At Westwood Plantation differential transport of body units at is supported by the evidence. However, to test whether this interpretation is accurate, it is necessary to look at other medium-sized mammal remains, such as domestic pig, recovered from Westwood. The introduction of domestic animals creates a novel environment and, as such, introduces the possibility of different procurement strategies.

No utility indices exist for pigs so credible comparison of pig and deer cannot be made with utility indices. As stated earlier, the indices from one species should not be applied to other species. However, a comparison of the two medium-sized mammals present at Westwood Plantation is essential to obtain a more accurate picture of what was occurring at the site. In general, all parts of a pig are utilized to some extent, even if just ground up for sausage or rendered down as lard (Eakins, 1924). Yet, when inspecting historical accounts of barreled pork, even the lower grades of "cargo" do not contain pig feet, though they may contain the heads (Berry, 1943). As such, it is a relatively safe assumption that foot parts – tarsals, carpals, metapodials, and phalanges – are low utility. Since the utility rank of all other body parts is questionable, only the appendicular skeleton is examined here. This is done by comparing the skeletal part frequencies of "low utility" pig parts to the frequency of the appendicular skeletal parts. Although the humerus, radius-ulna, tarsals, carpals, metapodials, and phalanges are all low utility deer parts, only the tarsals, carpals, metapodials, and phalanges will be considered in comparison to the rest of the appendicular skeleton of scapula, humerus, radius-ulna, pelvis-sacrum, femur and tibia. This is done to be make the comparison as accurate as possible. The researcher is aware that this comparison is problematic, but without utility indices for pigs, it is the best comparison possible.

The number of individual specimens (NISP) was figured for both white-tailed deer and domestic pig from Westwood Plantation (Appendix B). The total NISP of white-tailed deer remains present was 160, of which 80 are from the appendicular skeleton. Of those 80 appendicular bone fragments, 32.5 percent (N=26) were "foot" bones. The total NISP of domestic pig remains present was 281, of which 90 were from the appendicular skeleton. Of those 90 appendicular bone fragments, 32 percent (N=29) were "foot" bones. These numbers suggest a similar disposal method for both species.

Historical documents support the fact that domestic pig would have been raised on site (Hunter *et al.*, 1999). Since all the parts of a pig should be represented and nothing should be transported, the numbers suggest the material recovered was present as food refuse rather than as a result of differential transport. The deer remains are, therefore, probably food refuse as well, rather than transport. All the larger animals were most likely butchered in another area of the site that has yet to be uncovered.

The results for deer are potentially misleading given that Westwood Plantation is a historic site where both transport and differential disposal are possible causes for the resulting assemblage. Such a problem would not be encountered at a prehistoric site, where all faunal material would have been transported. However, there remains the possibility that butchery areas and consumption areas were separated prehistorically. Therefore, all faunal material should be considered when interpreting a site through utility indices use in order to attain an accurate picture of site activities.

Discussion

Although an interpretation was reached concerning Westwood Plantation faunal material, its analysis has revealed some problems that need to be addressed when applying utility indices. While the scatter plots were made using bone density, differential soil conditions across the site could affect taphonomy. Bone preservation and other factors could make interpretation of material from other sites more difficult than it was for the material from Westwood. Skeletal part frequencies can be affected by any number of factors. This project focuses on those factors influenced by transport and nutritional representation, and does not take into consideration all taphonomic variables that can affect bones. In addition, selection of bone as raw material for tools or other cultural implementation as a factor influencing bone representation is not considered.

Chapter VII

Summary

This project has addressed issues relating to interpretation of faunal remains from archaeological sites. First, it evaluated past methods of interpreting skeletal part frequencies, meat estimation, and utility indices construction. Second, it introduced valuable wildlife biology and animal science research and methodology into archaeological investigations. These methods were then applied in order to test the validity of utility indices construction. Third, and most importantly, this project focused upon the development of meat, marrow, and general utility indices for white-tailed deer. White-tailed deer had not been fully examined in this manner before. It also included an investigation of marrow fat percentages and how these relate to the marrow utility index.

The results of these investigations proved revealing. Through the use of marrow fat percentages it was possible to reconsider the use marrow utility indices based solely on weight. Also, the varying indices were investigated for differences due to age, sex, and season of death. The indices revealed the existence of some variation based upon sex and season of death, little variation based upon age once maturity was reached, but significant variation based upon age between juveniles and adults. Utility indices for white-tailed deer were then compared to other indices of similarly related species in order to demonstrate that applying an indices for one species to another species is not possible due to the variation that exists between species.

The utility indices were applied to archaeological material to test the usefulness in interpreting the archaeological record, as well as to address problems inherent in its use. The standardized general utility index (SGUI) was applied to archaeological material from a historic antebellum plantation and it was demonstrated that differences in economic utilization were apparent, thereby validating this research. However, problems with application do exist. One problem can arise if reliance is placed only upon the white-tailed deer remains without consideration of similar-sized mammals. Also, taphonomic processes and other factors affecting skeletal part frequencies, such as artifact manufacturing and use, need to be considered when attempting to interpret an archaeological site.

Utility indices are a useful tool for interpreting the archaeological record, but there is still room for improvement. In the future, it is hoped researchers will continue to develop utility indices for new species, as well as expand on the work already accomplished for many species.

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APPENDICES

APPENDIX A

Key Codes for Tables and Figures

Part	Abbreviations
skull	SK
mandible	MD
cervical vertebrae	CV
thoracic vertebrae	TV
ribs	RIB
lumbar vertebrae	LV
pelvis-sacrum	PS
scapula	SC
humerus	HU
radius-ulna	RA
metacarpal	MC
carpals	CA
femur	FE
tibia	TI
metatarsal	MT
tarsals	TA
phalanges	PH

Appendix B

NISP Counts of Westwood Plantation (16CT490) White-tailed Deer and Domestic Pig

Element	White-tailed Deer NISP	Domestic Pig NISP
antler	2	NA
astragalus	3	1
calcaneus	7	2
carpal	3	3
caudal vertebrae	2	0
cervical vertebrae	4	1
cranial	44	16
femur	14	6
fibula	NA	7
humerus	7	13
lateral malleolus	2	NA
lumbar vertebrae	2	0
mandible	4	21
maxilla	4	4
metacarpal	1	2
metapodial	2	6
metatarsal	4	6
pelvis	8	5
petrous portion	2	3
phalanges	0	3
radius	10	4
rib	4	4
sacrum	2	0
scapula	4	6
tarsals	0	1
thoracic vertebrae	2	5
tibia	9	15
tooth	10	134
ulna	4	5
Totals	**160**	**281**

VITA

Jodi A. Jacobson was born in Blacksburg, Virginia on June 25, 1974. She received most of her primary and secondary education in the public schools of Starkville, Mississippi. She spent one year overseas during sixth grade in Kathmandu, Nepal where she attended Lincoln School. She graduated from Starkville High School in June of 1992. She earned her B.A. in Anthropology from Mississippi State University in May of 1996. While at Mississippi State she participated in a variety of archaeological projects throughout the state of Mississippi.

In August of 1996 she entered the graduate program in Anthropology at the University of Tennessee, Knoxville. During the 1997-1998 school term she held a Zooarchaeological Research Assistantship in the UTK Department of Anthropology. During the 1998-1999 school term she held a Graduate Assistantship through the McClung Museum at the University of Tennessee. For the 1999-2000 term she was awarded a Graduate Teaching Assistantship in the UTK Department of Anthropology. While working on her Master's she participated in a variety of archaeological field projects around East Tennessee. She, also, has worked on faunal contracts for historic material from Tennessee and Louisiana. She will begin work towards a Ph.D. in Anthropology upon completion of a Master of Arts degree.